46TH CONGRESS, 3d Session. } HOUSE OF REPRESENTATIVES. { Ex. Doc. No. 95.

REPORT OF MISSISSIPPI RIVER COMMISSION.

LETTER

FROM

THE SECRETARY OF WAR,

TRANSMITTING

The report of the Mississippi River Commission.

MARCH 2, 1881.—Referred to the Committee on Commerce and ordered to be printed.

WAR DEPARTMENT,
Washington City, March 1, 1881.

The Secretary of War has the honor to transmit to the House of Representatives, in compliance with section 5 of the act of June 28, 1879, copy of the report of the Mississippi River Commission, dated January 8, 1881, together with the letter of the Chief of Engineers submitting same to the department.

In view of the importance of the subject, it is respectfully requested that this report be printed.

ALEX. RAMSEY,
Secretary of War.

The SPEAKER
of the House of Representatives.

OFFICE OF THE CHIEF OF ENGINEERS,
UNITED STATES ARMY,
Washington, D. C., March 1, 1881.

SIR: I have the honor to forward herewith a copy of a report from the Mississippi River Commission, dated January 8, 1881, and to suggest that it should be transmitted to Congress in compliance with section 5 of the act of June 28, 1879, creating the Commission.

Very respectfully, your obedient servant,

H. G. WRIGHT,
Chief of Engineers, Brig. and Bvt. Maj. Gen.

Hon. ALEXANDER RAMSEY,
Secretary of War.

REPORT OF THE MISSISSIPPI RIVER COMMISSION.

OFFICE OF MISSISSIPPI RIVER COMMISSION,
Saint Louis, January 8, 1881.

SIR: The Mississippi River Commission has the honor to submit the following report, embracing—

1. A statement of the progress made in surveys, observations, and examinations.

2. A preliminary report on the Upper Mississippi River, from the Falls of Saint Anthony to the mouth of the Missouri River.

3. A preliminary report on the method of improvement by means of reservoirs.

4. A report by a committee of this Commission on the subject of outlets and levees on the lower river.

NOTES OF PROGRESS.

The nature and scope of the field operations decided upon by the commission as the most advantageous application of the funds provided for its use were fully set forth in its first report, dated March 6, 1880.

In addition to the work then contemplated, at the request of the House Committee on Levees and Improvements of Mississippi River, Hon. E. W. Robertson, chairman, and with the approval of the honorable the Secretary of War, an investigation of the reservoir system has been undertaken, and part of the work now in progress, both in field and office, is in furtherance of this object.

Pursuant to the plans above referred to the work has progressed since March 6, the date of the last report, as follows:

Gauges.—Daily records have been continued at all the gauges established by the commission, and a collection of readings by other parties on the Mississippi and tributaries is being made. A determination of the relative elevations of the gauges is now in progress.

Triangulation.—One hundred and twenty-eight miles, between Helena, Ark., and Niblet's Landing, Miss., and 195 miles, between the mouth of the Illinois and the Ohio rivers, or in all 323 miles of river have been covered; a secondary base has been measured opposite Chester, Ill. Parties now in the field will complete the work to Cairo above and Greenville below. With work which the Superintendent of the Coast and Geodetic Survey informs the commission that he will be able to do by February 1, the close of the present season will find a chain of accurate triangulation extending from the mouth of the Illinois River to the Gulf of Mexico.

Topography and Hydrography was completed from Cairo to Memphis during last season, and has recently been commenced at Commerce, Miss. The work at that point has been temporarily suspended, and the party is now making a survey of the harbor of Vicksburgh.

It is expected that this part of the survey will be made continuous from Cairo to Vicksburgh during the present season. Charts of 120 miles of last season's work have been made in the office.

Precise Levels.—Three hundred and eighty-five miles have been completed since last report, consisting of 100 miles above Memphis, 120 from Friar's Point to Childer's, Miss., and 165 miles between the mouth of the Illinois River and the mouth of the Ohio River. The work of the present season by the commission, together with that projected by

the Superintendent of the Coast and Geodetic Survey, will complete the series of levels from the mouth of the Illinois to New Orleans.

Arrangements have been made, acting in concert with the Coast and Geodetic Survey, to connect the line with the mean level of the Gulf.

Examinations.—The series at Plum Point, Lake Providence, and Carrollton were continued for one year as proposed. As stated in the last report, these observations consist of the changes in the figure of the river bed at different stages of the water, the kind of material forming or moving along the bed, the figure and movements of sand waves, the slope of water surface, the discharge and the transverse curves of velocity. The valuable data thus collected are now being reduced. Parties have also been stationed at six points on the Mississippi River above Saint Louis, a party being at or just below the mouth of each important tributary. These parties are to be continued for one year, from October 1, 1880, to October 1, 1881. Their work will consist of a frequent measurement of the river's discharge and slope, and observations on the figure of the bed and its changes, the amount of sediment carried in suspension, and the nature of the materials composing the bed under different conditions.

A large number of marks of the highest point of the flood of 1880, at different localities below Cairo, have been obtained, and a party is now engaged in determining their elevations.

The slope of the water surface between Cairo and Commerce Cut-off (nearly 300 miles) was also taken at the low stage of November.

Borings have been made at Choctaw Bend, Greenville, and Lake Providence.

The meager data now available, concerning the swamp lands contiguous to the river, will be increased during the present season by running ten additional transalluvial level-lines between Cairo and Red River.

The total work done by the commission up to date may be summarized as follows:

Secondary triangulation	miles	559
Precise levels	do	515
Topography, hydrography, and low-water slope	do	243
Secondary base located and measured		1
Aggregate field work of observation parties	months	48
Gauges erected and read		13
High-water marks obtained of 1880 and previous years, about		200
Number of borings		17
Aggregate depth of same	feet	2,656
Charts projected and drawn		21
Harbor survey (Vicksburgh)		1

The following work has been done in part by the commission, and with the co-operation of the Coast and Geodetic Survey:

Secondary triangulations	miles	200
Precise levels	do	330
Secondary base located and measured		1
Harbor survey (Grand Gulf)		1

Of the work imperatively necessary to the preparation of comprehensive plans for the improvement of the river, the following, dependent for its execution upon future appropriations, remains to be done:

1st. Secondary triangulation and precise levels from the Falls of Saint Anthony to the Illinois River, or over such portions as may be found necessary to strengthen existing surveys.

2d. Topography and hydrography from Vicksburgh, Miss., to Baton Rouge, La. (243 miles), with extension of the details one mile or more from the river bank at numerous localities between Cairo and Red River.

3d. Further observations upon the discharge of the river below Cairo, particularly at flood stages, and upon the relative volumes of tributaries.

REPORT ON THE UPPER MISSISSIPPI RIVER, BETWEEN THE FALLS OF SAINT ANTHONY AND THE MOUTH OF THE MISSOURI RIVER.

It was the intention of the commission to continue this year a system of observations below Saint Louis that would have enabled it to mature a plan for the improvement of that part of the river. This work contemplated simultaneous observations, extending over an entire year, on and below each of the main tributaries. The estimate submitted last session included provision for this project. But the reduction of the appropriation by Congress rendered this work, or any part of it, impossible, as it was obvious that, to possess any value, it must extend over the entire lower river, must be conducted in the same year, and through the entire year. It was, therefore, reluctantly postponed, and the estimate therefor repeated in the amount sought at the hands of the present Congress.

In consequence of this disappointment, the commission decided that the next best thing was to inaugurate a similar study of the river above Saint Louis, this being a work of lesser magnitude, which the reduced appropriation would justify it in undertaking.

In pursuance of this amended project, the commission visited the river between Saint Paul and the mouth of the Illinois in the early part of the year, but the water was too high to afford proper opportunities of observation. Subsequently, in October during an exceedingly favorable period, this tour of inspection was repeated.

On these observations on the reports and surveys of General Warren, Colonel Macomb, Major Farquhar, Captain Mackenzie, and their assistant engineers, and on facilities and information courteously afforded by the last-named officer, now in charge of the works of improvement, this report is based.

The drainage basin comprises 33,719 square miles above Saint Paul, and 52,399 square miles on the right and 48,156 square miles on the left bank from that point to the mouth of the Illinois, 25 miles above the mouth of the Missouri. The immediate valley has an average width of about three miles, often, however, of double this, as below Muscatine, and again, crowded by the hills on both sides, as below Rock River.

The rocky limits of this valley have been filled in some places 100 feet deep with sand and gravel, in which the present river excavates and shapes its bed, in curves to which the bluffs are tangent, but never reaching the bed rock below. To these general characteristics there are two exceptions, one at Rock Island and one at Keokuk. Here the line of least resistance seems to have been through gorges in the adjacent hills, instead of the glacial drift obstructing the main valley. In these localities are therefore found rocky beds forming rapids which obstruct low-water navigation. Similar formations exist at Fountain Bluff and at the Chain of Rocks below Saint Louis.

At Rock Island, a channel 4 feet deep and 200 feet wide at extreme low water has been cut in the rock, while at Keokuk has been built a canal, affording a minimum navigation of 5 feet and a maximum of 8 feet.

The entire valley, except the sand terraces, is subject to flood inundation. The river courses from side to side, in a bed of shifting sands and gravel, which leaves its water nearly free from suspended matter. The changes occurring in the channel are constant, although not so rapid as in the lower river. They are produced and measured by the force directly applied to the material of the bed by the motion of the water.

The complications and uncertainties attending the improvement of

sedimentary streams, from the prolonged and even indefinite suspension and transportation of solid matter, and from the instability of the banks constructed thereby, are not found here. On either side of the main stream are sloughs, open at both ends, and also lakes, which are without outlet, except during floods. These lakes are sometimes of great depth. The sloughs give favorable opportunity for improvement, as they enable the engineer to control the force which he proposes to use in deepening the main channel.

Some of the tributaries sweep in large quantities of sand, forming a lake-like expansion and depth above, with slight fall, and a steep, uncertain, and difficult channel below. The most marked existing example of this is caused by the Chippewa, from the head of Lake Pepin, down to Alma. Here the process has been prolonged and intensified by the excessive sand discharge of this river; but an examination of surveys affords evidence of similar record at other tributaries, in the extinct lakes above, now a labyrinth of sloughs, ponds, and competing channels, and in the bad navigation below. The depths of the lakes adjacent to the river but beyond the impetus given to the sand by floods; the depth in the lower end of Lake Pepin, and the opportunity of lateral flood relief, indicate that the bed may be still rising.

The following factors enter into the regimen of the stream. The length from Saint Paul to the mouth of the Illinois is 645 miles, and the fall 278.56 feet, giving a mean slope of .432 foot per mile. The minimum is above the tributaries and rapids, as, .138 foot at Wacouter, above the Chippewa River; .168 foot at Prairie du Chien, above the Wisconsin River; .127 foot at Le Claire, at the head of Rock Island Rapids; .136 foot at New Boston, above the Iowa River; and .256 foot at Montrose, at the head of the Des Moines Rapids; and the maximum below the tributaries, as .580 foot, .629 foot, and .663 foot, between the Chippewa and Winona, and .533 foot at Oquawka, below the Iowa River.

From this statement Lake Pepin and the Rock Island and Des Moines rapids are omitted, being considered extreme cases.

An expression generally characteristic of width and cross-section is difficult, owing to the numerous islands, sloughs, and lateral channels. As a general rule the width, slope, and discharge increase with the drainage area, but a proportionate increase of depth is not found. The low-water observations this fall at stations established by the commission give the following relations between discharge and supply, at nearly the same stage (3.21) above low-water.

Place.	Discharge.	Per cent.	Drainage area.	Per cent.
Prescott	8,598	100	33,719	100
Winona	17,712	206	55,474	165
Clayton	22,816	289	74,865	222
Hannibal	42,600	496	129,635	384

The rise and fall are extremely uniform throughout the length, ranging at different points from 16 feet to 22 feet, the difference being apparently inversely proportioned to the opportunity of lateral expansion in floods. It increases towards the junctions with the Illinois and Missouri, being controlled by the greater oscillations of these rivers.

The low-water velocity may be stated at a mean at one mile per hour. In floods it increases to about three miles per hour.

These conditions, briefly described, are characteristic of a river well adapted to the labors of the engineer.

The statistics of commerce on the Upper Mississippi are given in the reports of the engineers in charge of the improvements for 1877 and subsequent years. The following information concerning its methods and requirements is submitted:

The present condition of the river does not afford a navigable depth over 5 feet for a sufficient part of the year to justify the construction of boats of greater draught. Even this depth, for a long part of each year, is not found above Keokuk; and during such times boats of sufficient dimensions to be economical as freight carriers are laid up and replaced by light-draught tow-boats and barges, the former drawing from 2½ to 4 feet, and the barges from 3 to 5 feet. Lumber rafts draw from 16 to 30 inches, but require a wide, straight channel.

Economy in transportation is largely dependent upon the capacity of the carrier, which increases in a more rapid ratio than the draught or cost of construction and operation. Barges on the upper river, built with a limit of draught of 5 feet, carry about 12,000 bushels of grain, while those used below Cario, where a depth of 8 or 9 feet can be obtained for a large part of the year, carry 20,000 bushels on 5 feet, 50,000 on 7 feet, and 60,000 on 8 or 9 feet.

It may be safely stated that the present appliances for this commerce are designed to fully utilize the navigation now afforded, and are limited and impaired thereby, and that the requirements of an economical and safe system of transportation will not be secured with less than 6 feet of water from Saint Paul to Saint Louis throughout the channel and throughout the year.

The depths now available at Rock Island and at Keokuk should not control a project to secure greater depth elsewhere, for the following reasons:

1st. In any plan of improvement the limit should be fixed by the more uncertain factors. While there may be doubt as to the extent to which any system can be carried in securing greater depth over bars, there can be no question that, however it may be pushed, at least an equal result can be obtained by the less experimental work of rock-blasting and canal-building at the rapids. While it would not be prudent to establish a standard depth at Rock Island and Keokuk, whose practicability was uncertain on other parts of the river, we need not hesitate in striving for the most extreme results elsewhere from doubts of their attainability at these two points.

2d. A depth of 6 feet throughout, except at these two places, would in itself, and independently of these controlling points, give great ease and safety to commerce. Navigation is not alone limited by the least depth encountered, but by the general character of the river. One or two controlling obstructions in a route of 700 miles may be tolerated, but a constant recurrence of such difficulties would destroy its value by accumulated danger and delay. For instance, boats can reach Hastings, 27 miles below Saint Paul, when they can reach La Crosse, 129 miles lower down, the ruling bars between these two places giving as much water as they do below La Crosse. But above this city they are much more frequent than below, and navigation is so greatly impeded that time and its attendant expenses consume all the profits of an extension of the run to Hastings.

The plan of improvement adopted for this part of the river consists of low-water dams closing sloughs, or side channels, to augment the flow through the main channel; of spur-dikes built out from concave shores, where the width is too great, to direct and concentrate the flow and produce scour over that part of the bed promising the best channel; of

revetments to protect such parts of the bank as may be attacked by the direction and concentration given to the current by the dikes.

The dikes consist of layers of stones and of brush, bound into fascines or mats. The details are described and illustrated by Major Farquhar's report for 1879. Both free and engaged ends are protected by additional and heavier work. Their usual inclination is slightly upstream, in order that the draft of water towards and discharge over the dike may be away from the bank, and also to check the race along and around the free end of the work.

The distance between these spur-dikes is greater than their length, the latter being controlled by experience, by the widths required for easy navigation, and by a theoretical consideration of cross-sectional area.

At first these dikes and dams were raised only about 1 foot above low water. They are now built about 4 feet above, and give more prompt and definite results. The additional height is of great advantage against ice, and as serving to indicate the location of the dikes, which, if concealed, might prove dangerous obstructions to passing boats. This last-mentioned benefit should be still more completely secured by the erection of beacons or lights on the free ends.

There is no evidence that the system of improvement has yet approached its practical limit, or developed any adverse operation or tendency.

Dredging has been occasionally resorted to, where erosion is very slow, or to secure landings in front of towns.

Inasmuch as all work heretofore done constitutes, both in location and construction, part of the final and complete plan, the application of the system simultaneously to all parts of the river needing improvement is highly judicious, both as giving results more generally useful and satisfactory, and as admitting a more tentative and experimental development of the system. The varied and contradictory experience and testimony of engineers concerning the improvement of rivers by this method rendered its cautious adoption necessary. The results are now fully justifying the judgment of the engineers in charge, and may be comparatively tabulated as follows:

Part of river.	Before improvement.	After partial improvement.
Saint Paul to Saint Croix *	16 inches	2 feet.
Saint Croix to Chippewa	1.5 feet	3 feet.
Chippewa to Wisconsin	20 inches	3 feet.
Wisconsin to Illinois	2 feet	3½ to 4 feet.

*Only two of the worst bars on this stretch improved.

The following local results are more indicative of the capabilities of the system, as the appropriations have not permitted work on all the shoals on any one reach:

Locality.	Before improvement.	After partial improvement.
	Feet.	*Feet.*
Pig's Eye	1.3	4.5
Nininger	1.0	3.7
Smith's	1.3	4.5
Mount Vernon	2.0	4.5
Betsy Slough	1.5	4.5
Winona	1.5	3.0
Queen's Bluff	2.5	3.6
Cassville	1.9	4.0

We do therefore agree in approval of the system and work of improvement now being conducted on the Upper Mississippi by Capt. A. Mackenzie, United States Engineers, and in the recommendation that it be prosecuted, with such modifications as experience may suggest, simultaneously on all the parts requiring improvement, as far as practicable under appropriations, with a view of securing a minimum depth of 6 feet from Saint Paul to Saint Louis.

Whether this work is done directly by the engineers in charge or by contract, it is equally essential that the sums appropriated be sufficient to justify the procuring of the complete and expensive plant necessary for the efficient and economical execution of such work. The appropriations heretofore made have not allowed the necessary provision by the government's agents, nor have they induced or justified parties qualified by large means and experience for the performance of engineering contracts to engage in this business.

We do therefore further recommend the adoption by Congress of the estimates submitted for the coming fiscal year by Capt. A. Mackenzie, United States Engineers, amounting to $1,000,000, equally divided on the river above and below Des Moines Rapids, with the understanding that the plans for the continuance of the work be submitted to this commission for its approval.

We also recommend that provision be made for the maintenance and operation of Des Moines Canal similar to that already made for the Louisville Canal. Such structures are always subject to accidents that cannot be foreseen or provided against. There is also the possibility of failure to pass the appropriation bill in which this provision may be included. Either of these contingencies would result in extreme loss and hardship to a very large class and to very great interests.

A letter from Captain Mackenzie, United States Engineers, relative to the commerce of the upper river, a statement relative to the works of improvement under his charge, and letters from parties experienced and interested in the navigation of the upper river are submitted as appendixes. (Appendixes B, C, and D.)

IMPROVEMENT BY MEANS OF RESERVOIRS.

This subject, though not embraced in the act organizing the commission, was referred to them during the past season, especial reference being had to the system of reservoirs proposed for the headwaters of the Upper Mississippi, Saint Croix, Chippewa, and Wisconsin rivers. At that time the field operations for the present season had been already laid out, and as the sum allotted by Congress for the use of the commission was considerably less than either their original estimate or their supplemental estimate, they did not feel justified in diverting any money from the more important Mississippi work to follow up this new subject of investigation. They had indeed been obliged to give up a projected scheme of observations on the lower river and to confine themselves to observations on the Upper Mississippi, because, although second in importance, they were less costly than those required on the main river. For these reasons the commission have mainly confined themselves to a careful revision of the data already collected by the Engineer Department, United States Army, which has from time to time been published in the annual reports of the Chief of Engineers, U. S. A. These data are confessedly imperfect and entirely inadequate for a satisfactory study of so important a subject, but as it is all that is available, the commission can at present only submit a preliminary and general report on the

subject. The surveys already made have shown that the country around the headwaters of the rivers in question seems fairly well adapted to the construction of storage reservoirs of considerable capacity, the more northerly streams having, however, the advantage in this respect. On the Upper Mississippi, in fact, the holding ground which might be obtained is considerably in excess of even the most favorable estimate of the amount of collectable water. On the other three streams the reverse is the case. On these latter rivers State concessions to private parties have led to the construction of numerous dams on the main streams and their tributaries, which are used in the interest of various lumber firms. These dams have thrown the projected government works high up towards the headwaters, where the number and choice of sites is restricted. This is doubly unfortunate, both as limiting the scope of the improvement and also its availability, unless the United States acquire jurisdiction over the private works lower down the streams. Otherwise, the parties owning or operating these private dams might have it in their power to interfere very seriously with the proper management of the improvement, or even to defeat it altogether. The attention of Congress is respectfully invited to this subject.

The engineer officers who have from time to time reported on this reservoir project have made various estimates as to the amount of water which can be impounded in the reservoirs and added to the low-water flow of the streams. The latest estimate allows a discharge from the Upper Mississippi series of 6,400 cubic feet per second for a period of 100 days. This estimate is necessarily somewhat hypothetical, as time and money have not been available for obtaining precise information on the subject. After a careful revision of the published data, the commission is forced to the conclusion that this may be an overestimate even for an average of several years, and that the low-water increment may not be as great as supposed. For years of minimum rainfall, which may not exceed 15 inches, the estimated increment certainly cannot be obtained. What the true amount will be cannot be at present stated, it can only be determined by careful gaugings of the streams which drain the various areas. These gaugings should extend over a full period of twelve months, and observations should at the same time be made to determine the annual precipitation to which the measured discharge corresponds. The determination of this matter with accuracy is absolutely essential, as the increment to the low-water discharge furnished by the Upper Mississippi series is by far the most important of all from every point of view, while all the estimates which have been made of its amount show but little if any surplus of collectible water over reservoir capacity, and if these estimates are too great, as now seems possible, the effect will have a serious bearing on the whole subject.

With regard to the three other rivers, the amounts estimated as collectible are so much in excess of the proposed reservoir capacity that any error in this estimate would have but little if any bearing on the result. In other words, the estimates are well on the safe side.

The last estimates furnished by the local engineer were as follows:

From Upper Mississippi series	6,400	cubic	feet	per	second.
From Saint Croix series	3,974	"	"	"	"
From Chippewa series	2,897	"	"	"	"
From Wisconsin series	2,084	"	"	"	"
Total	15,355	"	"	"	"

These amounts it was supposed could be furnished for a period of 100 days, so as practically to cover the low-water period.

This would insure a minimum discharge past Saint Paul of 12,200 cubic feet per second; below the St. Croix, of 20,474 cubic feet; below the Chippewa, of 24,461 cubic feet, and below the Wisconsin of 36,645 cubic feet.

The officer in charge of the work further gives his reasons for supposing that the increment to the low-water flow of the tributaries would insure them a good navigable depth, and would render any other system of improvement unnecessary, or at least reduce its extent. This matter does not come within the scope of the duties of this commission, and we have only to remark that, granting these assumptions to be correct, which we have no reason to doubt, the question would come fairly before Congress for its action, as a legitimate project for the improvement of the navigation of these tributary streams.

As concerns the effect likely to be produced on the main river, we cannot commit ourselves to a definite opinion till our observations on the Upper Mississippi shall have been completed. We can at present only state our views in the most general way as to what effect a reservoir system may be expected to produce upon a river like the one we are considering, with some comparison between the effects thus produced and those due to other well-known and long-tried systems of improvement.

In order to clear the ground for this discussion we desire to state that it will in our opinion be hopeless to look for any appreciable mitigation of the violence of floods from this or any other system of reservoirs yet proposed, nor does the local engineer entertain any such view. Destructive floods are generally due to local causes, heavy rains occurring in the vicinity of the main river, and floods from the lower tributaries superposed upon a swollen river. The effect of holding back a few thousand cubic feet of water from the discharge of the remote northern tributaries would have no appreciable result in preventing disastrous inundations in those portions of the main river where they now occur, and where alone damage from this source is to be apprehended. It remains therefore only to discuss the effect produced upon the low-water navigation.

In considering this subject, it is necessary to bear in mind that in the present condition of affairs we have really two entirely different rivers to deal with. First, we have the river at high stages, when a great volume of water flows along with an impetuous current, and banks a mile or more apart, while the vast masses of sand in motion, and the alternate building up and destruction of banks, bars, and islands attest the great energy of the stream. At low stages we have a shrunken and comparatively insignificant stream, its scanty volume one-tenth to one-fifteenth of the high-water flow, spread thinly over portions of the wide, high-water bed, while narrow, tortuous and shallow channels meander through the great sand deposits of the high river. Between these two extremes we have all possible conditions, but still the fact remains apparent that the flood stage is the ruling condition; that then the bed is shaped and defined, and that to the great disparity between the two conditions the difficulties of navigation are due; it is no question of the absolute size of the high river but simply of the difference between it and the lower stage. The system of channel improvement now in progress seeks to concentrate the scattered waters of the low stage, and by confining them within narrow limits to increase their scouring efficiency and insure stability of location. The results so far obtained have been of marked benefit, and the system can be extended almost indefinitely, though the absolute increase in navigable depth attainable is probably limited in

amount, and the works themselves are liable to be destroyed, or their contemplated effects negatived by the action of the high river over which they have no control whatever. It would therefore seem that, setting aside the question of cost, the only system of improvement which would insure permanency, and at the same time develop to the utmost the capabilities of the stream for navigable purposes, would attack the high river itself and endeavor to bring it under control.

In its present condition the great volume of flood waters is spread over a very wide channel, its depth being small in comparison with its width; at the same time its scouring power is frittered away, owing to the great extent of surface on which it acts or is expended in attacking the banks. The current, owing to frictional resistance, is slackened and the rapidity of discharge decreased, with a consequent increase in height of flood level. The materials torn from the banks, or brought in by tributaries, cannot be carried away, but gradually accumulates in the channel, forming obstructions, which, by deflecting the current, cause further caving of banks, accompanied by a local raising of the bed and the flood line. These accumulated masses of sand remain behind as the river falls, and form the bars which impede navigation at low stages.

Were the high river confined within such limits of width as theoretical investigation should show to be compatible with an efficient discharge section, and the banks protected from erosion, the scouring power of the stream, being concentrated over a moderate area, would soon form a deep channel, and the resulting deep and narrow section would be far more efficient than the wide and shallow one of the unregulated river. Owing to decrease in frictional resistance the volume of flood waters would be passed off more readily and rapidly, the mean velocity of the current would be increased, and the flood line would be lowered. The influx of sand from caving banks would be stopped, and that brought in by tributaries would be carried so far and scattered so generally as to prevent any local accumulation which would interfere with the low-water flow, while, as the river declined from the higher to the lower stages, the width and depth would regularly diminish till, at the lowest stage, if the improvement were properly proportioned, a width would be reached that would insure a depth ample for all purposes of navigation. This would also give a definite, stable channel free from the innumerable crooks and turns that now form such a formidable impediment to navigation. The commission cannot, from present information, lay down the dimensions or suggest the method of carrying out such an improvement, neither can they estimate its cost nor state whether it is financially possible; they simply describe it as the system which, if it could be carried into execution, would give the greatest attainable benefits, and to which any system followed out should approximate as closely as possible.

In its present unregulated condition the water in floods moves along vast masses of sand, which wholly or in part obliterate the channels of the previous season, and which, arrested in their motion when the fall sets in, remain as bars of greater or less dimensions. While the river is high the depth over their crests is probably sufficient, as a general rule, to allow boats to pass freely over them, but as the river declines this depth rapidly diminishes and soon becomes insufficient for navigation purposes. Then ensues a period of great difficulty, when the bars offer the greatest possible obstruction, and there is no defined channel anywhere. As the fall continues, the water ponds up behind the bars until a sufficient head is obtained to form a breach through them, which then becomes the navigable channel. This process, called "cutting

out," may be repeated several times in the course of the season, the depth and width diminishing and the tortuousness increasing. but, as a general rule, where only one channel at a time is formed, the depth, even at lowest stages, is much greater than obtains where there are several such channels, as occurs at all the bad bars, and it is upon this fact that the present system of low-water improvement is based.

This cutting out process is the turning point in the whole system of river navigation. After the river has fallen sufficiently to forbid further passage over the bars, everything depends upon the promptness and thoroughness with which the low-water channels are developed. When they are once formed, any considerable rise which may occur is apt to be injurious, unless it be sufficiently great to restore the depth over the bars; otherwise it will move sufficient sand to fill up or impair the newly developed channels, and restore the transition period already alluded to, with all its difficulties. The period at which the cutting out process sets in varies with the different seasons. A great flood is generally followed by a season of bad low-water navigation owing to the quantity of sand moved, and to the great extent of the changes inaugurated, but, as a general rule, the most important factor is the rate of decline from the high to the low stage. Even in the case of a great flood, the low-water channels may be in better condition if the flood be followed by a slow, gradual decline, than in the case of a lesser flood followed by a rapid or irregular decline. Anything, therefore, which reduces the rapidity of the fall from the higher stages is a benefit, probably in the direct ratio, of the amount of this reduction, and it is here that, in our opinion, the true effect of reservoir action must come in. If, as we take for granted, the impounded water is to be let out on the falling river in a volume measurably proportioned to the rate of depletion of the main stream, the effect will be to lessen the rapidity of the fall, and will therein prove a benefit so far as it goes. If the increment of flow were considerable, the effects would also be considerable, while probably little practical value would attach to an increment of small size. The period of transition is, however, still to be bridged over, unless the reservoirs furnish a sufficient supply to render the cutting out process unnecessary. If, however, they prolong the transition period, a result which may occur, they would temporarily be a positive detriment. After the low-water channels have been cut out, the increased discharge should certainly be beneficial, at least at those places where either from natural conditions or artificial works a single channel is formed. Where the river is much cut up with numerous shifting subsidiary channels, we should imagine the benefits likely to be derived from reservoir supply to be inappreciable. It must be borne steadily in mind, in considering this question, that nothing can be expected from the increase in discharge due to reservoir supply, over and above what would be found under normal conditions with a discharge of similar amount except the effects, already alluded to, as accompanying a lessening of the rate of decline from high to low stages.

Against any benefits accruing from a reservoir system must be set the great uncertainty attendant on their use; the difficulty and cost of maintenance and operating; the variations in rainfall from year to year, giving at times an excessive and at times a deficient supply; and finally the risk of the rupture of one or more dams, with the loss of the impounded water and other damaging effects. These uncertainties would doubtless deprive such a system of improvement of much of its estimated value.

We are therefore of the opinion that a reservoir system that shall

efficiently supersede other methods of improvement will have to be of sufficient magnitude to control a large proportion of the river discharge; if of less magnitude, the direct benefits will be somewhat doubtful, but will be greater on a regulated than on an unregulated river.

We have no reason to doubt that the Upper Mississippi River is susceptible of direct channel improvement to any reasonably desired extent without the aid of reservoirs.

The question whether reservoirs can be advantageously used as adjuncts to the contraction of river width on which the channel improvement depends is mainly one of cost.

An increase by reservoirs of the low-water flow would diminish the amount of contraction of low-river width which otherwise would be neceessary, thus diminishing its cost, while above Prescott the greater width which thus might be adopted for the regulated river would be of value; but if, on further study, the construction of one or more of the reservoirs which furnish water at the cheapest rate should be deemed advisable, they would be valuable only after the contraction of the river had been carried to the fullest economical development, and not till then should they be built.

The uncertainty surrounding the subject can only be removed by extended and systematic observations as to the amount of water that can be collected and stored up in reservoirs, and also as to the effect which may be expected to follow its addition to the low-water flow of the river. In order to carry out these observations we estimate that $27,000 will be required.

There is a possibility that the system is capable of greater extension than is now contemplated. It is obviously desirable that this point should be settled, and that the whole subject of dam location should be revised, the sites proposed for dams more carefully examined, and the estimates of cost placed on a surer basis than at present. For this purpose a further sum of $22,000 will be needed.

We also beg leave to recommend, as a measure of ordinary prudence and economy, the withdrawal from entry of such public lands as are liable to be overflowed by any reservoir the construction of which may be decided on as part of a comprehensive system, and such legislation as will place these streams throughout their entire length under the control of the United States before any work is begun.

The efficient use of the best reservoir system is not consistent with the ownership and control by private parties or corporations of any dams below the reservoirs.

The possible benefits to be derived from an efficient reservoir system may be briefly summarized as follows:

First. Such a system would perhaps in some degree aid, in the manner hereinbefore discussed, the low-water navigation in the main river below Saint Paul as far down as the mouth of the Saint Croix, a distance of 30 miles. But these benefits would be greater and more certain upon an improved river than they possibly could be if the impounded water is supplied to the stream in its present unimproved condition.

Second. It would give a needed supply of water during the low-river stage to the mills at the Sauk Rapids and at Minneapolis, on the Mississippi, and at various localities on the other rivers.

Third. It would aid in some respects the lumber interests on the Mississippi River above Saint Anthony's Falls, and on the tributaries named, until the adjacent lands are deforested.

It is therefore apparent that the interests to be subserved by the construction of reservoirs at the headwaters of the Mississippi, Saint Croix,

Chippewa, and Wisconsin rivers are not in any great measure identical with those which are directly dependent on the improvement of the navigation of the main stream below the Falls of Saint Anthony.

It seems proper to state that Major Allen, the local engineer in charge of these reservoir investigations, who has freely placed the records of his office at the disposal of the commission, has stated that he regards his last estimate of $1,400,000 for the construction, and $208,000 for the first ten years' maintenance and operation of the entire reservoir system, as considerably too low. He now places the cost of construction and ten years' maintenance at about $2,000,000, exclusive of land damages. If we estimate the land damages at $1,000,000 to $2,000,000, the reservoir system maintained ten years will cost from $3,000,000 to $4,000,000, and at this cost can only be regarded as an auxiliary to the method of direct channel improvement now in process of execution. In this view Major Allen coincides.

Captain Mackenzie's estimate of the cost of securing by direct means a 6-foot channel from Saint Paul to Rock Island, a distance of 397 miles, is $2,847,900. Below this the reservoir system cannot be expected to have any appreciable effect.

RECAPITULATION.

In recapitulation, the conclusions of the commission may be stated as follows:

First. The system of works in progress on the Mississippi River between Saint Paul and mouth of the Illinois River, with the modifications which experience will suggest, is adequate for the improvement of navigation, and should be pushed rapidly to completion.

Second. A sufficient improvement of the river is not to be expected from the action of a system of reservoirs alone.

Third. It is possible that on the completion of the observations now in progress, some of the proposed reservoirs which furnish water at the least cost, may be found to be economical aids to the principal system of channel contraction. But they should only be built when the works for channel contraction approved have been carried to the fullest economical development.

Fourth. It is recommended that the entire amount of $1,000,000, estimated by Capt. A. Mackenzie for the coming fiscal year, for carrying on the adopted improvements between Saint Paul and the mouth of the Illinois River, be appropriated in one sum.

Fifth. It is recommended that the Des Moines Rapids Canal be placed upon the same footing as regards maintenance, operation, and repairs, as the Louisville Canal.

Sixth. It is recommended that the sum of $49,000 be appropriated for continuing the observations, examinations, and surveys necessarily required as preliminary to a trustworthy estimate of the capabilities and cost of an efficient reservoir system.

OUTLETS AND LEVEES.

As embodying further information touching the effects of outlets, dams, and levees upon the regimen of the lower river, a report by a committee of this commission is appended. Inasmuch as the facts stated in the report bear more or less directly upon subjects embraced and treated at some length in the first report of the commission, and in the minority report thereunto appended, it has been deemed proper

to place the paper in this form before Congress, without entering upon any discussion thereon at the present time.

All of which is respectfully submitted.

Q. A. GILLMORE,
Lieutenant-Colonel of Engineers, Brt. Maj. Gen.,
President Mississippi River Commission.
C. B. COMSTOCK,
Major of Engineers and Brt. Brig. General.
CHAS. R. SUTER,
Major of Engineers, U. S. A.
HENRY MITCHELL,
Coast and Geodetic Survey.
B. M. HARROD.
BENJAMIN HARRISON.

This report is concurred in by me, with the exception of that part of it which relates to the improvement by means of reservoirs.

I have not sufficiently investigated this subject to justify an opinion upon it.

JAMES B. EADS.

Hon. ALEXANDER RAMSEY,
Secretary of War.

LIST OF PAPERS ACCOMPANYING THE FOREGOING REPORT.

APPENDIX A.

FINANCIAL STATEMENT.

OFFICE MISSISSIPPI RIVER COMMISSION,
Saint Louis, Mo., December 11, 1880.

Balance February 16, 1880, as per statement accompanying report of March 6, 1880	$90,000
Amount appropriated by act approved June 16, 1880	150,000
	240,000
Amount expended February 16, to December 11, 1880, including outstanding liabilities:	
For surveys and observations, salaries of commissioners, mileage, and inspection, office and general expenses	135,000
Balance, which it is estimated will be required during the remainder of fiscal year ending June 30, 1881	105,000
	240,000

SMITH S. LEACH,
First Lieutenant of Engineers, Secretary of Mississippi River Commission.

APPENDIX B.

LETTER OF CAPT. A. MACKENZIE, CORPS OF ENGINEERS.

UNITED STATES ENGINEER OFFICE,
Rock Island, Ill., December 2, 1880.

DEAR GENERAL: Your letter of 29 is received. Our information relating to dimensions and draughts of boats and barges on upper river is not as definite as it should be. My answers to your questions will not, therefore, be as satisfactory as I would like to make them.

The largest boats navigating my stretch of river are the side-wheel boats of Keokuk Northern Line. Two or three of the heaviest of these form a line from Saint Louis to Keokuk, the others run through from Saint Louis to Saint Paul or La Crosse as stage of river permits. The draught to which these boats can be loaded, depends on depth of hold, which (excepting War Eagle) will not, I think, exceed 6 feet. The depth of hold of these boats and their barges can be obtained accurately from Keokuk Northern Line office, in Saint Louis. It is difficult to say what depth of water is desired by steamboatmen. Their present boats are built to suit present condition of river, and if a 6-foot channel were guaranteed, perhaps they would give a greater depth of hold. My own opinion is, though, that the class of boats now running will accommodate upper river commerce for all time, as the bulk of freight will be carried in barges. The raft and tow boats draw from 2½ to 4 feet, and on the latter draught a very powerful tow-boat can be built. Lumber rafts draw from 16 inches to 30 inches. Barges now in use are loaded to from 3 feet to 5 feet, the latter figure being about extreme capacity. The barge Strasburger of Keokuk Northern Line will carry 12,000 bushels of wheat on draught of 5 feet.

Colonel Macomb's estimates for 5 feet to Rock Island and 4½ thence to Saint Paul were based on grades of Des Moines Rapids Canal and Rock Island Rapids. The depth of 4 feet on Rock Island Rapids was fixed by a Board on ground that such a depth would afford better navigation than was found in river above. A special report on Rock Island Rapids is inclosed. The ruling depth on the rapids should not control the proposed depth at other points on account of effect of greater depth on speed. A boat drawing 4 feet to run and handle well should have at least 6 feet and her speed will be considerably increased on a depth of 8 feet.

Our theoretical estimates are based on a depth of 6 feet from Saint Paul to the mouth of the Illinois. There is not enough water in river at lowest stages to secure a greater depth than 6 feet on extreme upper part unless the river is converted into a canal. On the other hand a depth of 6 feet at least from Saint Paul to mouth of the Illinois will, I have no doubt, be ample for all purposes of economical transportation. When there is plenty of water boats occasionally load to the capacity of their hold from 4 feet to 6 feet.

During high spring floods ice barges sometimes come down drawing 10 feet, but these are exceptions. As the river falls boats are loaded to a less draught and sometimes they are not loaded at all, freight being carried on their barges.

The large side-wheel boats run during the greater part of the season, but during low water do not go up higher than La Crosse. They could always reach Hastings as well as La Crosse, but between these points the crossings are so numerous and deep pools so short that the river is, as they term it, very "slow." When the river gets very low the heavier boats are laid up and the business is done by long light-draught stern-wheelers and barges.

Boats load a few inches deeper below Keokuk than from that point to La Crosse. I have been told that the class of boats running from Saint Louis to Keokuk should be able to load to at least 5 feet to make trips pay. Below Keokuk the minimum depth on bars is no greater than above, but the pools are deeper and longer and boats can load to full depth of water on shoalest reef and even a few inches deeper. Above Keokuk the number of shallow reaches is greater, and constant laboring with slow time would result from deep loading. At extremely low stages, which do not last much longer than one month in a season, but unfortunately occur when greatest amount of freight is ready for shipment, we may say that we are liable to have from Saint Paul to Hastings not more than 20 inches, from Hastings to La Crosse, since worst points have been improved, not less than 3 feet, and from La Crosse down from 3½ to 4 feet.

Of the largest boats the greatest draught loaded is about 7 feet for War Eagle, 6 feet for others, and the minimum draught about 3 feet.

As regards our bench-marks, a large number are on trees, but many are reasonably permanent, being on rock or stone foundations of warehouses or on bridge piers. In fact, above Rock Island these permanent marks are quite close together. We propose next season, if it is possible, to establish permanent benches over the whole district.

I am, very respectfully,

A. MACKENZIE,
Captain of Engineers.

General C. B. COMSTOCK.

APPENDIX C.

MEMORANDA RELATING TO WORKS OF IMPROVEMENT ON THE UPPER MISSISSIPPI RIVER BETWEEN SAINT PAUL AND THE MOUTH OF ILLINOIS RIVER (ROCK ISLAND AND DES MOINES RAPIDS EXCEPTED).

The first works of any magnitude for the improvement of the Upper Mississippi River were begun in 1878. Prior to this time some experiments in closing chutes by dams of stone and brush had been made by the United States steamer Montana, and with very satisfactory results, at Pig's Eye Island and Ninninger Slough, two points between Saint Paul and Hastings.

COST OF THE WORK TO DECEMBER 1, 1880.

On June 18, 1878, Congress appropriated $250,000 for improvements between Saint Paul and Des Moines Rapids, of which $20,000* were directed to be expended in the trial of Adams's flume.

(NOTE.—Nothing has yet been done with the flume, and no information can be given as to its efficacy.)

On the same day $100,000 were appropriated for work between Des Moines Rapids and the mouth of the Illinois River. As no accurate information was at hand concerning the amount and character of the work needed on this 650 miles of river extending from Saint Paul to the mouth of the Illinois River, it was deemed best at the outset to cause a thorough survey to be made of the entire stretch of river, with a view to studying the same and obtaining the necessary data for plans and estimates for a comprehensive system of improvements. This survey, including the office work and preparations of maps, plans, and estimates, has cost $82,000, and it is considered that the money has been well spent, as without the information obtained from such a survey it would be working in the dark to attempt to present plans and estimates on such data as could be obtained from casual observation and hearsay evidence. On March 3, 1879, Congress made a further appropriation of $100,000 for the river from Saint Paul to Des Moines Rapids, and $40,000 for the river between Des Moines Rapids and the mouth of the Illinois River, and again on June 14, 1880, $150,000 for the river above, and $100,000 for the river below Des Moines Rapids. From these latter appropriations $10,000 to the *Gen. Barnard* for removing snags, &c., to aid in preparing the shores for riprap, and for repairs to dams and other works.

The statement below will show the amount received by appropriation, the amount expended to December 1, 1880, for improvements, and the amount still available for the work.

Money Statement.

Appropriation above Des Moines Rapids.

June 18, 1878	$250,000	
March 3, 1879	100,000	
June 14, 1880	150,000	
Total above Des Moines Rapids		$500,000

Appropriation below Des Moines Rapids.

June 18, 1878	100,000	
March 3, 1879	40,000	
June 14, 1880	100,000	
Total below Des Moines Rapids		240,000
Total for Upper Mississippi River		740,000
Expended for surveys, &c	82,000	
Expended for Adams's flume	20,000	
Allotted to steamer Barnard	10,000	
Balance available December 1, 1880, to complete works already begun	134,000	
		246,000
Amount expended on improvements		494,000

*This amount of $20,000 came out of the next appropriation of $100,000, instead of the $250,000 as stated.

RECORD OF IMPROVEMENTS.

AT PIG'S EYE BARS.

As before mentioned, a dam was built in 1874 across the head of the Eastern Chute, which resulted in the improvement of the crossing at the head of the island. In 1878 between the foot of Pig's Eye Island and Kaposia ten spur-dams were built, which have deepened and strengthened the channel at this formerly very bad locality.

NEWPORT BARS.

Newport Chute was closed in 1878, and one spur-dam built above head of island. The depth of water in the crossing has been materially increased.

NINNIGER SLOUGH.

A dam was built by the *Montana* in 1875 across the head of this slough, which caused a material deepening in the main channel.

HASTINGS TO PRESCOTT.

In 1878 seven dams, including the closing of Prescott Island Chute, were built on this stretch of 3 miles of river. In 1879 the right bank below Hastings was protected for a distance of 800 feet, and also 1,250 feet shore protection was built at Dibble's Point to prevent the river from breaking through into Lake Saint Clair. There is now good water along the shore below Hastings and at head of Prescott Island, which in former years were points of very great obstruction to navigation.

SMITH'S BAR.

This bar, which was the worst obstruction between Prescott and Chippewa, was thoroughly improved in 1879 by construction of 5 wings and 1,000 linear feet shore protection.

RED WING.

The north channel leading to Lake Pepin was closed in 1880, with a view to increasing the amount of water in the middle and Wacouta channels; 2,075 feet of shore protection were built.

CRAT'S ISLAND.

In 1878 three dams were built at this locality, and the crossing at the head of the island improved. In 1879, 1,977 feet of shore protection were constructed on left bank, and in 1880, in order to complete the work and improve the crossing at foot of Crat's Island and the crossing above Tepeota Point, two spur-dams were built and 737 feet shore protection.

AT BEEF SLOUGH.

The operations at this locality in 1878, consisting of five dams and considerable shore protection, resulted in the improvement of the long crossing below Tepeota Point. In 1879 and 1880 the project for this locality was completed, and it is hoped that the work already done will give a good river from Wabasha to Alma, formerly perhaps the worst piece of river of the Upper Mississippi. The work of 1880 consisted of six dams and 6,100 feet shore protection.

AT HEAD OF WEST NEWTON ISLAND.

Pomme de Terre Slough was closed in 1880 near its head, and the island shore protected for a distance of about 1,200 feet. It is expected that the effect of this dam will be the improvement of West Newton Bar, as also of the river from head of West Newton Island to Mount Vernon, which is sometimes very bad, especially in the vicinity of Minneesha.

MOUNT VERNON BAR.

This most troublesome bar was eradicated in 1879 by construction of six dams and 250 feet shore protection. This is one of the most successful works now completed.

ROLLING STONE BARS.

Work has been carried on at this locality for the last three seasons, and the improvement is now nearly completed. In 1878 four dams were built and considerable shore protection; in 1879 two dams and 1,000 feet shore protection; in 1880 two dams were raised and one dam built, as also about 700 feet shore protection.

BETSY SLOUGH BAR.

This improvement, carried out in 1878 and 1879, has resulted in removing one of the worst bars on the Upper Mississippi River, viz, the crossing at foot of Betsy Slough.

ABOVE WINONA.

The project for work at this locality is now nearly completed, and marked improvement is shown in the crossing above the bridge. Seven dams and some 3,600 feet of shore protection were built in 1879 and 1880.

QUEEN'S BLUFF BAR.

This very bad bar was eradicated in 1879 by the construction of two spur dams from the Minnesota shore.

AT LA CROSSE.

The work in vicinity of La Crosse, consisting of several closing dams and about a mile of shore protection, was done partly by the Saint Paul Railroad Company, partly under special appropriation, and partly under the appropriation from Saint Paul to Des Moines Rapids, all the work being under the supervision of the government. It has resulted in the improvement of the river from the head of Minnesota Island to foot of Grand Island below La Crosse.

AT GUTTENBERG.

Work on improvement of Guttenberg channel was begun late in 1880, but cold weather soon put a stop to operations.

FOOT CASSVILLE SLOUGH.

The improvement of this very bad bar has been effected by work done in 1879 and 1880, consisting of three dams and 1,800 feet of shore protection. A towhead much in the way of rafts, situated about a mile below Glen Haven, was removed.

DUBUQUE HARBOR.

A large amount of dredging was done at this point in 1877, 1878, and 1880 on the bar in front of the levee. The lower portion of the bar has been removed and the landings much improved, as well as the ferry crossing.

BELLEVUE BAR.

In 1878 the eastern chute was closed, and although the work is not considered completed, the result is very beneficial.

ROCK ISLAND HARBOR.

Under special appropriation considerable dredging was done at this point in 1880 along the landing, and much benefit was secured.

HORSE ISLAND.

Work at this point consisted in the removal of bowlders and patches of rock from the channel. This locality is now considered permanently improved.

MUSCATINE HARBOR.

Considerable work has been done under special appropriation in dredging at Muscatine.

KEITHSBURG.

A large amount of bowlders, clay, and gravel were removed by dredge from the long crossing below Keithsburg in 1879 and 1880.

RUSH CHUTE AND BURLINGTON HARBOR.

Work has been in progress at this locality for several years, but owing to the smal amount of special appropriations, has not yet been finished. It is hoped in the coming spring to complete the permanent improvement of Rush Chute. Much good has resulted from the dredging along the Burlington City front.

SHOKOKON SLOUGH.

Work was begun with a view to closing Shokokon Slough, and thus improving the very bad river on the west side, between head and foot of Burlington Island, some 6 miles of river. Cold weather interrupted the work, which will be resumed in the spring.

VICINITY OF DALLAS AND PONTOOSAC.

Several low dams were built in 1878, contracting the width of the river. Some dredging was done at head of Dallas Island, and a large quantity of bowlders were removed from the Pontoosac crossing.

NEAR ALEXANDRIA.

Work was begun in 1880 at this locality under special appropriation. for the purpose of improving the famous Warsaw crossing and preserving the harbor of Alexandria. One dam was completed and another well under way when lack of funds compelled cessation of operations.

ABOVE GREGORY'S LANDING.

Work was begun in 1880 for the improvement of the bad bar above Gregory's Landing, but ice on the river put an end to operations after the work was well started. It is hoped to finish the work in the spring of 1881.

VICINITY OF CANTON.

Canton and Smoot chutes were closed by dams and 1,000 feet shore protection built in 1879. The result has been to turn the channel over the Missouri shore, much shortening the distance as well as improving the harbor of Canton. Much more work will be needed in the stretch of the main river, extending from head to foot of Canton Chute.

VICINITY OF QUINCY.

Under special appropriation, the very bad crossing in front of Quincy was thoroughly improved in 1879 by the construction of a wing-dam from the Missouri shore. Much dredging has been done in Quincy Bay with a view to establishing an ice-harbor.

HARBOR OF HANNIBAL.

Under special appropriation, a large amount of dredging has been done in the harbor of Hannibal, and much good has resulted therefrom. Two dams have been built with a view to keeping the channel on the Missouri shore, and thus prevent the refilling of the dredged area.

AT GILBERT'S ISLAND.

Much work has been done in this vicinity in the past two seasons, and much remains to be done in order to effect a permanent and radical improvement. The difficulties to be overcome were very great, but it is hoped that the coming season will show good results. Nine dams and 10,800 feet of shore protection have been constructed.

AT SLIM ISLAND.

Some 4 miles of very bad river were thoroughly improved in 1879. The works consisted of five dams and 4,800 feet of shore protection. This is the most successful work below Des Moines Rapids.

AT WESTPORT CHUTE.

Work was begun on this very bad piece of river late in 1880, and was soon interrupted by ice. It will be resumed early in the spring.

SUMMARY.

Improvements made to December 1, 1880.

Locality.	Date.	Condition.
Pig's Eye Bars	1874 and 1878	Completed.
Newport	1878	Do.
Hastings to Prescott	1878 and 1879	Do.
Redwing	1880	Do.
Crat's Island	1878, 1879 and 1880	Do.
Beef Slough	1878, 1879 and 1880	Do.
Mount Vernon	1879	Do.
Rolling Stone Bars	1878, 1879 and 1880	Nearly completed; good results.
Betsy Slough	1878 and 1879	Completed.
Above Winona	1879 and 1880	Nearly completed; good results.
Queen's Bluff	1878	Completed.
Vicinity of La Crosse	1877, 1878 and 1879	Finished to foot of Grand Island.
Guttenberg	1880	Begun.
Foot Cassville Slough	1879, 1880	Completed.
Dubuque	1877, 1878 and 1879	Good progress made.
Bellevue Bar	1878	Do.
Rock Island Harbor	1880	Begun; good results.
Horse Island	1878, 1879 and 1880	Completed.
Muscatine	1877, 1878 and 1880	Good progress made.
Below Keithsburg	1879 and 1880	Do.
Rush Chute and Burlington	1877, 1878 and 1880	Burlington work finished. Rush Chute improvement nearly so.
Shokokon Slough	1880	Begun.
Dallas and Pontoosac	1879	Do.
Near Alexandria	1880	Do.
Above Gregory's Landing	1880	Do.
Vicinity of Canton	1879	Begun; good results.
Vicinity of Quincy	1879 and 1880	Bar improved; good progress on ice-harbor.
Harbor of Hannibal	1880	Good progress.
Gilbert's Island	1878, 1879 and 1880	Four miles river improved.
Westport Chute	1880	Begun.
Slim Island	1879	Four miles river improved.

LOCALITIES TO BE IMPROVED.

There follows a list of bars that must be improved to secure from 4 to 4½ feet at low water between Saint Paul and mouth of Illinois River. The bars below enumerated having been improved, there will still remain a large number of bars, which it will be necessary to improve in order to secure 6 feet, but these latter are not at present taken into consideration.

List of bars requiring improvement to secure 4 to 4½ feet at low water between Saint Paul and Des Moines Rapids.

List of bars.	Condition.	List of bars.	Condition.
Frenchman's Bar	Very bad.	Guttenberg Channel	
Island No. 2 Bar	Do.	Hurricane Island	
Red Rock Bar (two crossings)	Do.	Below Findley's Landing	
Below Newport		Specht's Ferry	
Robinson's Island Bar	Very bad.	Parson's Bar	
Island No. 10 (above Pine Bend)		Above Dubuque	
Boulanger's Bar	Very bad.	Nine-Mile Island	
Nininger Slough	Do.	Deadman's Bar	
Above Nininger	Do.	Mouth of Galena River	
Foot Nininger Slough	Do.	Above Bellevue	
Foot Prescott Island		Sand Prairie	Very bad.
Island No 20		Arnold's Bar	Do.
Diamond Bluff Bar		Keeler's Bar	Do.
Head Lake Pepin	Very bad.	Above Savanna	
Below Read's Landing	Do.	Below Dark Slough	
Above Wabasha	Do.	Island 281	
Pine Island Bar		Above Lyons	
Above Minneeska		Wapsie Bar	
Island No. 50		Cordova Bar	
Above Chimney Rock	Very bad.	Vicinity of Buffalo	
Below Chimney Rock		Above Oquawka	
Weld's Bar		Below Oquawka	
Argo Island		Burlington to Dallas	Very bad.
Vicinity of Homer		Pontoosac	
Above La Moille		Appanoose	
Below Trempeleau		Below Fort Madison	
Opposite Richmond		Above Nauvoo	
Dakota		Above Montrose	Very bad.
Dresbach	Very bad	Tully Island	Do.
Grand Crossing	Do.	Smoot's Bar	Do.
Island No. 110		Wyaconda Bar	Do.
Head Coon Slough		Whitney's Bar	Do.
Coon Slough Bends	Very bad.	Armstrong Island	
Broad Axe Bend	Do.	Mundy's Landing	Very bad.
Head Crooked Slough		Below Louisiana	Do.
Valley Crossing		Krider's Bend	Do.
Below McGregor		Foot Slim Island to Hamburg	Do.
Wyalusing		Cap au Gris	
Vicinity of Clayton (two crossings)		Dardenne Island	
Glen Haven Chute		Enterprise Island	Very bad.

Those marked *very bad* will be first improved, and as many of them in 1881 as funds will permit.

As it has been demonstrated by work already done that the Upper Mississippi can be materially improved by the methods now being carried out, and having shown the great amount of work remaining to be done, the following facts are given to show why large annual appropriations are needed for the successful continuance of the work, as the complete improvement of the river, even with liberal appropriations, must occupy several years, and as changes are continually going on, estimates made long in advance are of but little value, but the closest approximation now possible places the cost at about $10,000 per mile, or $6,500,000 for the entire length of river from Saint Paul to the mouth of the Illinois River (Rock Island and Des Moines rapids excepted), provided annual appropriations are large enough to do the work systematically and economically; with limited appropriations the cost will be materially increased. The total amount given is for a length of 650 miles of river, in which are included many long stretches now good and which may not require improvement for many years to come.

The total figure, though large, is small as compared with the interests involved, as it is an estimate for providing a transportation route of unlimited capacity.

An appropriation of $500,000 is asked by the Engineer Department for the Mississippi River from Saint Paul to Des Moines Rapids, and the same amount for the river from Des Moines Rapids to the mouth of the Illinois, or $1,000,000 for carrying on the improvement of over 650 miles of river, for the fiscal year ending June 30, 1882. Under large appropriations work can be done much more economically and to better advantage, contractors and the government being able to put into the field sufficient plant in the way of steamboats, barges, &c., which could not be done in case of small works; under small appropriations, allotments must be made for many bars, with probably insufficient money to *complete* the improvements at any of them, whereas with large appropriations sufficient sums can be allotted to each locality to finish the work at that point.

The improvement of a single bar, or of a few bars, only benefits navigation to an inconsiderable extent, but by attaching and improving simultaneously all the bars of a certain degree of "badness," the river may be improved to a limited extent all along the line. After the first series of works are completed, boats loading deeper will meet with another set of bars not quite so bad as the former, and these can be improved the next season. Thus, in each year the full benefit of all improvements will be derived, and so on until the entire improvement is completed. When a work is begun it should be completed at once, as otherwise the result of work already done may be lost, owing to frequent changes on the river. As long as the entire river is not put under control, changes will continually go on, and for this reason it is unwise and inexpedient to present long in advance definite plans and estimates, but while the proper system is being followed such plans are unnecessary. It is considered, therefore, better to ask for *one* appropriation for a given length of river, than to ask specific sums for individual localities, as the river may so change, in the time between the estimate and the receipt of the appropriation, as to make the bars appropriated for good for the time being, and others, not before so prominent, the worst of all.

The amount asked for may appear large, but it must be remembered that it is the aggregate estimate for a large number of separate works. If appropriations were asked for each locality separately, as can ordinarily be done, the individual sums would appear small.

With an appropriation of $500,000 for the river from Saint Paul to Des Moines Rapids, work can be done in a single year which will render the river as good from Saint Paul to La Crosse as it is now from La Crosse to Des Moines Rapids, and also greatly improve the river from La Crosse down, and the expensive transfer of freight and passengers now made in low-water periods at La Crosse or Winona can be done away with. In regard to the section of river between Des Moines Rapids and the mouth of the Illinois, the points of obstruction are comparatively few, but generally each embraces a long stretch of river and they are thus very expensive to improve. It is, then, important that the appropriation be large enough to admit the allotment of a sufficient sum to each selected locality to complete the improvements at that locality.

But perhaps the most cogent reason of all in favor of a large appropriation is, that by carrying on the work already commenced, as speedily as possible, the benefits to be derived from improvements may be secured at once.

APPENDIX D.

CIRCULAR LETTER OF CAPT. A. MACKENZIE, CORPS OF ENGINEERS.

UNITED STATES ENGINEER OFFICE,
Rock Island, Ill., December —, 1880.

M ——:

It is desirable in connection with a continuance of the improvements of the Upper Mississippi to know to what extent work already done has benefited commerce.

I should be glad to have your opinion as to whether the work heretofore done has benefited the class of navigation in which you are interested, and what additional work or modifications of plans are needed to make the improvement complete and navigation safe.

Very respectfully, your obedient servant,

A. MACKENZIE,
Captain of Engineers.

MESSRS. W. J. YOUNG & COMPANY.

OFFICE OF W. J. YOUNG & CO.,
STEAM GANG-SAW MILLS;
Clinton, Iowa, December 4, 1880.

DEAR SIR: Your favor of present month, December, 1880, at hand. In reply will say we think a large amount of good has been done to navigation of the Mississippi River by your commission, and yet we think that you have only demonstrated in a miniature way the great possibilities of making the Mississippi River one of the best navigable rivers in the world, and it should not be neglected any longer; the United States is able, and we believe the people of the United States are willing, to make liberal appropriations to carry forward this great national work, and we trust that

the importance of the work will be truly and faithfully presented to the present Congress, and that liberal appropriations will be made.

We would most respectfully call your attention to another matter of much needed improvements in river, namely, guard-booms or piling properly located at each bridge so as to insure more safety to passages of boats and rafts. It is not an uncommon occurrence for our boats as well as passenger-boats to be detained a whole day and night on account of danger of getting through when there is a stiff breeze blowing; we think that every bridge that our boats pass through with rafts costs us not less that $25 more than it would if there was no bridge there. Now let us count from Beef Slough to Clinton, La Crosse, Dubuque, and Sabula, three bridges, makes $75; and seventy to eighty rafts. It will be safe to say we will average eighty rafts per year, and with present mode of passage through bridges it will cost us $6,000 per navigable season. Will you please call Mr. Weyerhauser's attention to this, and see how near he agrees with this statement, and we do wish you would call attention of all navigators of Mississippi River between Saint Louis and Saint Paul to this matter of so great importance. Pardon this long letter, hastily written, about these matters of much importance.

Very truly, yours,

W. J. YOUNG & CO.

A. MACKENZIE,
Captain of Engineers, U. S. A.

LETTER OF MR. P. S. DAVIDSON.

LA CROSSE, *December* 6, 1880.

DEAR SIR: I think the improvements done along at different points on the upper river have been the means of making a good channel where the channel was bad. I think the work has done all that could be expected of it.

Work of a similar kind is needed at the following points: Between Wabasha and Reeds, at West Newton, Homer, Dresbach, Coon Slough, and Bad Axe. If those places were fixed I think we would have a pretty good channel in this part of the river.

Yours, truly,

P. S. DAVIDSON.

Capt. A. MACKENZIE.

LETTER OF THE DANIEL SHAW LUMBER COMPANY.

EAU CLAIRE, WIS., *December* 6, 1880.

DEAR SIR: I inclose a letter from Capt. A. Mackenzie, of the United States Engineer service at Rock Island, Ill., which explains itself.

I have written him regarding the Chippewa River improvement, and said I would request you to call a meeting of steamboat men at your place and Read's Landing, and ask you to forward to him a copy of any resolutions you might pass.

Yours, very truly,

THE DANIEL SHAW LUMBER COMPANY,
EUGENE SHAW, *General Manager.*

Capt. JOS. BUISSON,
Wabasha, Minn.

RESOLUTIONS, ETC., ADOPTED BY MEETING OF MASTERS AND PILOTS.

READ'S LANDING, MINN., *December* 11, 1880.

DEAR SIR: In accordance with the above request, at a meeting of the undersigned masters and pilots of steam-vessels engaged in towing logs and lumber on the Upper Mississippi, between Saint Paul and Saint Louis, held at Read's Landing, Minn., December 11, 1880, Capt. Daniel Davidson was appointed chairman and Capt. J. M. Turner, secretary.

The following preamble and resolutions were adopted:

Whereas the United States Government for several years past have been putting in jetty dams and riprapping the shores in divers places on the Mississippi River, between Saint Paul and Saint Louis, for the purpose of deepening the channel of said river in the interests of commerce:

Resolved, That in our opinion said dams, and the location of the same, are of great benefit to the navigation of the Upper Mississippi River and to the lumbering interests

generally, and more especially the dams placed in the mouth of the Chippewa River, and a few miles in and above the mouth of said river, at a place known as Flower Pot, and also the several dams placed in the Mississippi River at divers places between Wabasha, Minn., and Alma, Wis.

Resolved, That at the present time the most serious and dangerous obstacles to the navigation of rafts of logs and lumber, towed by boats on the Mississippi River, are the railroad bridges and their approaches, and we believe the following improvements would materially obviate the dangers of this class of navigation, and we earnestly recommend them to your favorable consideration:

1st. At Winona Bridge, by a continuation of piling and planking the same as above the La Crosse Bridge, to the upper end of Elevator, above said Winona Bridge, on the west side of the river.

2d. The piling below the La Crosse Bridge, on the Minnesota shore, including a building placed on said piling, is a greater obstruction to the navigation of rafts than the entire bridge, and should be removed.

3d. A pier placed at or near the head of the island, above Clinton Bridge, with a strong boom fastened to said pier, said boom to continue down river to the lower end of stone pier of bridge next to the island. The object of this pier and boom is to sheer rafts off from said bridge pier. Said pier in its present situation is extremely difficult to avoid, and annually does more damage to this class of navigation than it would cost to construct said pier and boom.

4th. A boom fastened to trees on the east shore near said Clinton Bridge, extending from stone pier of said bridge next to shore up river a distance of 1,500 or 2,000 feet. The object of this boom is to keep rafts from running over the bank in a high stage of water, and to sheer rafts off from said bridge pier.

5th. We recommend the same as above, a pier and boom at the Burlington Bridge, to sheer rafts off of the bridge pier on the west bank of the river, which is as dangerous a place to navigate rafts as at Clinton Bridge.

6th. We recommend piling and planking for a short distance above the abutment approaching the Keokuk Bridge on the west side of the river. This is not only very dangerous for rafts in passing said abutment, but also for boats and barges.

7th. We recommend that before commencing any of the above improvements, that the United States Engineer service engage the services of two practical and competent raft pilots to point out the above places and give their opinions and advice as to the location and kind of improvements necessary to make this class of navigation less dangerous than at present.

Resolved, That as this class of commerce and this class of navigation, viz, boats towing logs and lumber, is largely in excess of all other kinds of commerce and all other kinds of navigation on the Upper Mississippi River, we deem it the duty of our government to make the above much-needed improvements without delay, especially when the cost of making such improvements will scarcely exceed the damage done to rafts of logs and lumber, boats and barges, during the navigation of one single year.

Signed by—

DANIEL DAVIDSON.
J. M. TURNER.
HUGH DOUGLAS,
Master Steamer Clyde.
E. C. BILL,
Master Steamer Buckeye.
JOHN S. WALKER,
Master Steamer Silver Wright.
S. B. WITHROW,
Master Steamer.
WILLIAM YOUNG,
JOHN BUISSON.
JOHN YOUNG.
WILLIAM DOBLER.
HENRY YORK.
HENRY BUISSON.
CYP. BUISSON.

A. MACKENZIE,
Captain of Engineers.

LETTER OF MR. SAMUEL VAN SANT.

DAVENPORT, IOWA, *December* 7, 1880.

DEAR SIR: Yours received. The work already done has greatly improved the river. This year we have had but very little trouble in upper end where we are always forced to split and run our rafts in two pieces during the low stage of water. It would

have been much more difficult and expensive had it not been for stopping up the sloughs, building wing-dams, riprapping the shores, &c. What is known as the Beef Slough River has always been our greatest dread, and still is to a certain extent, but it has been vastly improved, and no doubt with another year it will be a terror no longer. Betsy Slough, so long a sure "sticking place," is as good as any part of the river. So is the river just above Winona. This season no trouble there. Last season, before improvement, as many as eight or ten boats have been there at one time, either in trouble or waiting for others to get out. Cassville Slough has been made much better also, and with the work already done and the removal of the little island toward upper end, we will be able to run our rafts through said slough without splitting. In fact our steamer, Silver Wave, on her last trip with a very large raft (15 strings) ran through whole without any trouble. We run very little below Rock Island, but no doubt the work below has been just as effective. I think I express the universal sentiment of all steamboatmen when I say that I hope the government will continue the good work until the grand old river will be one of the best navigable streams in the world. The government has done much and can do more. We earnestly hope it will do it.

We meet with more or less detention at all the bridges. If there could be heavy booms leading from above down to the piers between which we usually run it would greatly facilitate matters. Then if the draw-span to each bridge through which we usually run was piled and planked similar to the La Crosse Bridge, it would be a great benefit. La Crosse Bridge gives very little trouble, day or night, with a raft or barges in tow. Clinton Bridge, owing to the narrow spans and very narrow draw, is by far the worst bridge we have. In high-water we run down Illinois shore and have to split. We could be greatly benefited by a stiff boom from shore abutment, running up river 100 feet; and even less might do. Excuse long letter.

Very respectfully, yours,

SAM. VAN SANT.

Capt. A. MACKENZIE,
United States Engineers.

LETTER OF MESSRS. INGRAM, KENNEDY & CO.

OFFICE OF INGRAM, KENNEDY & CO.,
DEALERS IN LUMBER, LATH, AND SHINGLES,
Eau Claire, Wis., December 7, 1880.

DEAR SIR: Your communication of December, making inquiries in regard to the work done for the improvement of navigation on the Upper Mississippi River, is at hand and noted, and will say in reply that the work thus far done has been of very great advantage to the navigation of boats and rafts, and the same is true in regard to the work done in the Chippewa River. Had it not been for the work done by the government at the mouth of the Chippewa, we could not have run our rafts or boat during the low water of the past season, and think the plan you are working is the right one to secure the best results. If the bridges or the spans run by rafts were protected by a strong timber boom supported by piers, so that a raft or barge could be dropped against it and drop through, it would be of very great advantage; in fact, safe for that class of navigation.

Respectfully, yours,

INGRAM, KENNEDY & CO.

A. MACKENZIE,
Captain of Engineers.

LETTER OF MR. HUGH DOUGLAS.

WABASHA, MINN., *December 7*, 1880.

DEAR SIR: In regard to the improvements on the Upper Mississippi by the government, at all the points as far as my knowledge goes have been of great service, and with a little addition to what has been done the navigation will be good in the lowest stage of water.

Yours, with much respect,

HUGH DOUGLAS.

A. MACKENZIE,
Captain of Engineers.

LETTER OF MR. A. REILING.

BELLEVUE, IOWA, *December* 8, 1880.

MY DEAR SIR: Yours of the 3d instant at hand, and as to my opinion of the work already done on the Upper Mississippi and the benefit derived thereof, would be hard to estimate and to do it justice.

When I look back to former years when I used to lay at Tepeola for three days and no boat could pass up or down until they were removed, and also at Mount Vernon, Rolling Stone, Betsy Slough, and Bellevue Bar, and the latter especially when there were nine boats lying at one time, and had the appearance of the levee at Saint Louis. But since your improved (dam) there has been comparatively no trouble, only that the dam may have a tendency to change the channel below, as it did at Wabasha, for if you will remember, for two years it was almost impossible for rafts to get by, but this summer there was no trouble, but it left the sand below it, and it will take some time to cut out a channel, and by pursuing the course already commenced, to wit, confining the water to one channel as near as nature has intended, is the only way it can be accomplished.

You are aware the lumber interest exceeds that of any other branch, and should be protected. You are fully aware that there are a great many bridges, and a great many disasters occur, and especially to raft boats. These bridges should be compelled to pile or to boom, the same as you have at Rock Island and La Crosse; the latter at one time was one of the hardest bridges to go through, and now the easiest in consequence of the piling.

Any further information I may be able to give you, or any suggestion I may be able to make, I will only be happy to do so.

Yours, very respectfully,

A. REILING.

P. S.—Being called away from home was the cause of my not making bids on contracts.

R.

Capt. A. MACKENZIE.

LETTER OF MESSRS. DIMOCK, GOULD & CO.

OFFICE OF DIMOCK, GOULD & CO.,
MANUFACTURERS WOODENWARE, LUMBER, &C.,
Moline, Ill., December 8, 1880.

DEAR SIR: Referring to yours of the 3d instant, we wish to say that we have delayed replying until we could confer with the captain of our steamboat, who was absent at the date of receipt of your letter.

We are now pleased to say that he informs us that the improvements which have been made by the government under the supervision of the Engineer Corps of the United States, upon the Upper Mississippi River, have been of very great advantage to its navigation, and we hope that further appropriations commensurate with the magnitude of commerce upon the stream will be liberally made for a continuance of improvements in the same direction.

Respectfully,

DIMOCK, GOULD & CO.

Capt. A. MACKENZIE.

LETTER OF MR. J. C. FOLLMER.

NORTH LA CROSSE, *December* 14, 1880.

SIR: I received a communication from you requesting my opinion of the work already completed on the Upper Mississippi River.

Whether my opinion be worth anything or not, I will briefly state what I know from actual observation. No pilot will deny but what the dams at Wabasha, Mount Vernon, Betsy Slough, Black River, Cassville Slough, Bellevue Bar, and in fact all of them that have had any time to operate have improved the channel from 50 to 100 per cent.

At the foot of Beef Slough, in my opinion, there will be good water next season. We could not expect much benefit from it the past season, as there was a large amount of sand to be moved.

I can conceive of no better plan for improving the channel than the one already adopted.

As to what further improvement is necessary, I will say there are several places that could be made better for rafting; for instance, at the head of Richmond Slough there are three channels, none of which are very good. Dresbach is another. This was about as shoal a place as we had below the foot of Lake Pepin. The water could be confined in one or the other of the channels and have good water at all times. If in such places the water was confined to one channel there would be no trouble. Below the mouth of Fever River is a similar place. Foot of Muscatine Prairie and Skunk River Flats, by your place, could be greatly improved.

Not wishing to weary your patience, I am, respectfully, yours,

J. C. FOLLMER.

Capt. A. MACKENZIE.

LETTER OF MESSRS. WEYERHAUSER & DENKMANN.

SIR: In compliance with the request contained in your recent circular letter, we beg leave to make the following statement of the benefits growing out of the work already done on the Mississippi River to our class of navigation.

Our pilots mention the improvement at the mouth of Beef Slough, although only partially completed, as being very important, and express the hope that it will be completed at an early date.

The dams at Mount Vernon, at head of Rolling Stone, at Horse Shoe, and from the Wisconsin shore opposite Horse Shoe Bend, have improved the channel considerably. If the first three dams should be raised, a further improvement would follow.

A considerable benefit is derived from riprapping the bend above Fountain City. This might be extended advantageously.

The improvement at Betsy Slough, including riprapping of the bend, those at Winona Bridge, at Hammond Chute, including riprapping bend on Wisconsin shore, are very valuable.

The dams across the heads of sloughs in the vicinity of La Crosse very materially deepen the channel. The height of some of them should be raised. Our pilots are agreed that the improvements at the foot of Cassville Slough have effected a great saving for them of time and money, and would respectfully suggest that the bend be still further riprapped. The improvements at Bellevue are beneficial, but should be greatly extended. The dam across the slough opposite Bellevue should be raised.

And further, we beg leave to call your attention to the following much-needed improvements, viz: The piling at Winona should be extended farther up the river and planked, as at La Crosse. At the Sabula Bridge piling should be put in from the shore pier to the pork-house, and planked. At the Clinton Bridge piling should be put in from the second pier east of the draw to the head of the islands. If with this piling sheer-booms, as at the Rock Island Bridge, should be hung, the undersigned feel assured in saying that the handling of rafts at the bridges would be much cheapened, and conducted with comparative safety.

We would further suggest that buoys be placed in the Rock Island Rapids to indicate the raft channel to raft pilots.

Very respectfully,

WEYERHAUSER & DENKMANN.

A. MACKENZIE,
Captain of Engineers.

LETTER OF MESSRS. DUNANT, WHEELER & COMPANY.

TOW-BOAT LINE, DUNANT, WHEELER & CO.,
Stillwater, Minn., ———, 1880.

DEAR SIR: Your letter of a late date is received, and in answer to your inquiry of "What is your opinion as to whether the work heretofore done has benefited the class of navigation in which you are interested?" we answer very unhesitatingly that it has. Our boats, of which we have five, all engaged in rafting, ran all last season; the water at no time getting so low in the channel as to cause any material trouble, which we are well satisfied would not have been the case had it not been for the improvements made by the government. We have no suggestions to make. The system is good, and we think the parties in charge are thoroughly conversant with what is needed.

We would like to make a few suggestions in regard to some of the bridges, if it comes within your suggestion.

First, the Winona Bridge. If the piling could be extended along the west shore from the railroad depot to the old elevator, and planked, making a smooth surface from the

elevator to head of west draw pier; and at Clinton Bridge; a sheer-boom from head of Rock Island to second pier east of draw pier. The distance is something like 500 feet. This is one of the most difficult bridges to run with a raft in high water, on account of cross-currents and narrowness of spans. During the extreme high water of the past season scarcely a raft passed the bridge without damage, which we think could be entirely obviated by a sheer-boom. There are other bridges which we would like to see improved, but these we have mentioned seem to us to be of most importance.

Yours, respectfully,

DUNANT, WHEELER & CO.

Capt. A. MACKENZIE.

LETTER OF MESSRS. M'DONALD BROTHERS.

McDONALD BRO., TOW-BOAT LINE,
DEALERS IN LOGS, LUMBER, COAL, CORDAGE, AND BOAT SUPPLIES,
La Crosse, Wis., December 16, 1880.

DEAR SIR: We regret that the absence of the writer has so long delayed this communication. We beg leave to state that the work so far done under your direction and under the direction of your predecessors has been of very great advantage to us in our business of towing rafts of logs and lumber.

Our opinion is, that the general system under which you are working is the best at present known. There is, of course, a great deal more to be done. You have demonstrated in your system of dams, which narrow and define the channel during a low stage of water, the absolute certainty of obtaining the requisite depth for profitably navigating the river.

We do not feel warranted in suggesting any modification of your present plans, as we feel fully assured that you, and all in your department, feel an absorbing interest in making your work successful; and if any modifications should be needed, they will more readily occur to you, as you are perpetually noting the effect of your various works, than to us, who merely know that we are receiving very great benefit from what you have already done.

Yours, truly,

McDONALD BROS.

Capt. A. MACKENZIE,
Corps of Engineers.

LETTER OF MESSRS. C. LAMB & SON.

C. LAMB & SON,
MANUFACTURERS OF LUMBER AND SHINGLES,
Clinton, Iowa, December 16, 1880.

DEAR SIR: We own yours in regard to improvements on the Upper Mississippi River. We should say that what has been done has been a great benefit to commerce. We are sure at points it has assisted us quite largely in getting our rafts down, and certainly, if the work is continued, it must assist navigation largely. Just what additional work should be done we are not engineers enough to recommend. Think some arrangement of booms at the several bridges above here would assist largely in passing the bridges in night-time and stormy weather, and with more safety.

Yours, truly,

C. LAMB & SON.

A. MACKENZIE,
Captain of Engineers.

APPENDIX E.

REPORT OF COMMITTEE ON LEVEES AND OUTLETS.

NEW ORLEANS, *November*, 1880.

SIR: The Committee on Levees and Outlets report as follows:

For many years after the early settlement of the alluvial lands of the Mississippi River, the banks were of quite different character from that now prevailing. It is established that the concave bends, which are now protected by immense levees, with occasional heights of from 15 to 18 feet, then conformed, in profile, nearly to flood

height. In these bends were frequent and well-defined outlets, discharging at high-water. Travel along the bank in flood time was impeded by them. At least twenty or thirty of them were found on the west bank, from Plaquemine to Red River, some 50 or 60 feet wide.

The unobstructed efforts of nature in bank construction still tend to produce similar results. All old rivers or cut-off lakes have high banks, intersected by sloughs. The concave bank of Lake Concordia, examined by this commission last year, is a case in point—the grade being very high throughout, and in places above any known high-water, while six or eight outlets communicate through it with the adjacent swamp. A profile thereof accompanies this report.

All delta extension is made in this way, the banks being built up to high-water and pierced by outlets. Crevasses are naturally closed by a general fill on the banks, except where a few well-defined sloughs maintain themselves for a long time, subdividing in the rear, delta-like, into smaller channels. The old plank road at Ashton is as free from deposit to-day as when first built, with fills on both sides from 5 to 8 feet high.

Outlets are of two distinct origins: First, old passes, in different stages of extinction, such as Pass Manchac and Bayou Lafourche. These are not found above the first tributary or bluff. The second class of outlets—overflow coulées—such as Bayou Plaquemine and Bayou Saint James, Missouri, is found wherever there are lateral swamp drains. The flow of these may be in either direction, as the head is in the river or swamp. The origin of the Atchafalaya is in doubt. It may belong to either class of outlet, while it is highly probable that it is the dissevered trunk of Black River.

Every outlet of the Mississippi, above the Forts, except the Atchafalaya and the Lafourche, has been closed; and they all so remain, excepting those in the abandoned line of levees on the right bank, above Cypress Creek.

The changes in the river bank, from the condition described, consist of the increase of caving, the widening of the bed, the moving back of concave shores to where the deposit has been small, and the arrest of the bank-building process by the exclusion of sediment-charged flood waters by levees.

A comparison of the widths of the river from the point below Donaldsonville to New Orleans, as shown by the Delta Survey in 1851, and by the United States Coast and Geodetic Survey in 1875–'76–'77, is herewith submitted. This comparison is made at points which can be clearly identified on both charts.

Comparison of widths (from Delta Survey in 1851 *and United States Coast and Geodetic Survey in* 1875–'76–'77) *from Company Canal to Point Houma.*

1.	Above Canal	2,666	2,550	—116	
2.	*Carrollton avenue	2,460	2,300	—160	
3.	*Nine-mile Point	2,100	2,100		
4.	Kennedy Sugar-house	2,700	2,875		+175
5.	Jefferson Road	1,940	2,111		+171
6.	Osgood's Sugar-house	1,986	2,100		+114
7.	*Cavaillon's Road	1,720	1,920		+200
8.	Dussuan, lower line	2,100	2,200		+100
9.	Dussuan, upper line	2,075	2,275		+200
10.	*Salient Rose Levee	2,125	2,165		+ 40
11.	Labranche Sugar-house	1,965	2,000		+ 35
12.	Soniat Sugar-house	2,200	2,225		+ 25
13.	Red Church	2,375	2,540		+165
14.	Ormond Road	2,250	2,360		+110
15.	Above, narrowest	2,100	2,050	— 50	
16.	*Above, widest	3,200	3,525		+325
17.	Wid. Labranche Road	3,300	2,366		+ 66
18.	Roseland Road	2,170	2,140	— 30	
19.	Gipsy, lower line	2,200	2,225		+ 25
20.	*Levee Salient, on right	3,020	3,285		+265
21.	*Levee Salient, on left	2,750	2,800		+ 50
22.	California	1,700	1,800		+100
23.	Bonnet Carre Church	1,970	2,060		+ 90
24.	Camelia, upper line	2,250	2,200	— 50	
25.	*Watson's, lower line	2,225	2,150	— 75	
26.	Watson's, Levee Salient	1,965	1,965		
27.	* Watson's, upper line	2,665	2,525	—140	
28.	Sheppard's, upper line	2,100	2,325		+225
29.	Vacherie Road	1,975	1,830	—145	

* Indicates batture or accretion.

30. *Valcour Aime Salient	2,690	2,505	—185	
31. Roman	2,666	2,616	— 50	
32. *Theriot, upper line	2,333	2,666		+333
33. Convent	2,340	2,400		+ 60
34. Saint Cecile	2,486	2,486		
35. Colomb, lower line	1,770	2,000		+230
36. Rapidan	1,833	1,999		+166
37. Winchester, upper line	2,250	2,333		+ 83
38. Midway between 37 and 39	1,999	2,083		+ 84
39. Cofield's, lower line	2,000	2,100		+100
40. Point Houma	2,138	2,222		+ 84
	89,757	92,337	−1,001	+3,621
		89,757		1,001
		2,620		2,620

Average width in 1851	2,244.
Average increase of width, 0.0292 per cent	65.5
Average width in 1875–'76–'77	2,309.5

The average of forty measurements gives an increase of 65.5 feet, or 0.029 per cent. As the Delta Survey was made at a higher stage than the Coast Survey, and the measurements were made between water lines, the result does not fairly represent the increase of width. Wherever battures are forming, the difference would be considerable. No exact means were available for continuing this comparison higher up the river.

It is evident that the widening of the river does not measure the recession of the concave banks, but only the surplus of erosion over accretion. The examination of widths showed that where the river had widened tens, it had moved bodily, hundreds of feet.

There is no evidence of any progressive increase of flood heights, as the result of the building of levees. Any such tendency has probably been met by the widening and deepening of the bed. There is, however, reason to believe that the reduction of the elevation of the banks now makes artificial restraint of the flood waters necessary, and that the abandonment of levees and reopening of outlets would be to destroy navigation and promote destructive floods, particularly in localities where a 50-foot rise, restrained by a 12-foot levee, leaves a 6-foot low-water channel.

The construction of levees on the Mississippi River was commenced at New Orleans in 1720. Their extension was encouraged, and even enforced, under French rule, and, at the time of the cession to Spain, 1763, they extended continuously, on both banks, 20 miles below and 30 miles above the city, besides isolated settlements at Pointe Coupee, Manchac, Lafourche, and elsewhere. Little progress was made by the Spaniards, but, "by 1828, levees were continuous from New Orleans nearly to Red River Landing, except above Baton Rouge, on the left bank, where the bluffs rendered them unnecessary. Above Red River they were in a very disconnected and unfinished state, on the right bank, as far as Napoleon.

"In 1844, the levees had been made nearly continuous from New Orleans to Napoleon, on the right bank, and many isolated levees existed along the lower part of the Yazoo front. Above Napoleon few or none had been attempted."

The act of September 28, 1850, granting swamp lands to the States, for drainage and reclamation purposes, gave great impetus to levee building; so that, by 1858, it reached its greatest extension. In that year levees were complete from Commerce to the Saint Francis, excepting about 25 miles; and, also, from the Saint Francis to Cypress Creek, excepting about 57 miles. Thence down, they were continuous on the right bank. The 57 miles unbuilt was in a stretch of river to be discussed hereafter, and included the mouths of the White and Arkansas rivers.

On the left bank the system was complete. The levees not only restrained floods, but closed outlets through which the river discharged into swamps, at mid and lower stages.

The damage by the flood of 1858 is given hereafter. From Commerce to the Louisiana line it has not been repaired, except to a limited extent, by private parties, mainly below Cypress Creek.

The present condition of the levees is tabulated as follows:

* Indicates batture or accretion.

LIST OF LEVEES.

Location.	Miles built. Distance.	Right bank.	Left bank.	Remarks.
Forts to New Orleans	70	70	70	
New Orleans to Baton Rouge	132	132	132	
Baton Rouge to Red River	73	73	0	Hills on left bank.
Red River to Glasscock's	45	0	0	Hills on left bank. Overflow on right bank rediscbarged by Red River.
Glasscock's to Sargent's Point	113	113	0	Hills on left bank.
Sargent's Point to Delta	18	0	0	Hills on left bank. Overflow on right bank checked by Walnut Bayou.
Delta to lower end of Mississippi levees	33	33	0	Drain of Yazoo Bottom.
To Arkansas line	51	48	51	
Arkansas line to head of Lower Mississippi district.	175	.....	175	Breaks unknown on right bank.
Between Mississippi districts	10	.....	0	Do.
Upper Mississippi district	94	.....	94	Do.
Norfolk to Cairo	271	.....	0	Breaks unknown on right bank. Hills on left bank.
Cairo to Cape Girardeau	50	.....	0	Hills on left bank. Breaks unknown on right bank.
	1,135	469	522	

Right bank:

Miles of levee built	469	
Miles of levee unbuilt	66	
Miles of levee unknown condition	600	
		1,135

Left bank:

Miles of levee built	522	
Miles of levee unbuilt	10	
Hills and opening for draining Yazoo bottom	603	
		1,135

Profiles of several of the larger levees accompany this report.

Letters relating to levees, from engineers in Mississippi, are also filed.

The present drift of the condition of the river is steadily from bad to worse. The logical end is banks rising only to the level of the swamps, with the loss made up by additional height of levees, which will then range from 15 to 25 feet. Breaks in such levees mean destructive floods and the loss of navigation. The alternative is the abandonment of the production and commerce of the valley.

Your committee desires to call attention to three localities illustrative of the effects of outlets and levees.

FIRST.—CUBIT'S CREVASSE.

In 1863 Cubit's Gap was opened. It soon attained a width of half a mile and a depth of 108 feet. A report of the United States Coast and Geodetic Survey recently submitted to this commission shows a mean fill of 3.9 feet below this crevasse over an area of about 2½ square miles, and a maximum fill of 108 feet, between 1866 and 1877. The flood of 1880 below New Orleans exceeded all previous high-water marks by 6 to 12 inches. At all other parts of the river the flood of 1874 was much higher than that of 1880. But the natural closing of the outlet, which was very rapid between these two dates, accompanied by the progressive formation of the bar (there being no flood of magnitude to cut it out, as the outlet closed) produced the abnormal flood elevation above stated.

SECOND.—JUNCTION OF MISSISSIPPI, RED, AND ATCHAFALAYA RIVERS.

Much attention is due to the consideration of affairs at Red River. Shreve's cut-off, in 1831, severed from the Mississippi the bend in which Red River discharged, and from which the Atchafalaya was supplied. Prior to this the navigation of lower Red River was impaired by back-water from the Mississippi, which occasionally extended to Alexandria, on the Red, and to Monroe, on the Ouachita. The Atchafalaya

was rafted heavily. After the cut-off, Red River sought the Mississippi by the shortest route, through upper Old River, north of Turnbull's Island; while lower Old River, from the head of the Atchafalaya to the Mississippi, silted up and bore a heavy willow growth. Until 1865 Bayou Plaquemine was open, and through it and the Atchafalaya was the navigable approach to the Attakapas, Opelousas, and Atchafalaya country. To maintain this route the State of Louisiana removed the raft obstructing the streams. To this work, and the disturbance of the equilibrium between the Mississippi, Red, and Atchafalaya rivers by the cut-off, due the enlargement of the latter stream.

It will be observed that, for several years after the cut-off, the discharge of Red River passed to the north of Trumbull's Island. In 1873, after great enlargement of the Atchafalaya, lower Old River, silted and grown up, cut out, and the northern channel closed, in which condition it now remains. Down the Atchafalaya had become the line of least resistance, and only the surplus discharge of Red River passed beyond its head along the south channel to the Mississippi.

As the Atchafalaya continued to enlarge, its demands became more exacting, and this surplus was so reduced and uncertain that lower Old River became a wide, shallow, slack-water basin, receiving sediment alternately from the Mississippi and Red rivers. In 1876, this process had nearly closed low-water connection; and the waterway near the lower end of Turnbull's Island was only about 100 feet wide and 20 inches deep, with a fall of about 2 feet in a quarter of a mile towards the Atchafalaya. By the end of the low-water season, this bar cut out. In 1877 a similar bar formed nearly a mile towards the Atchafalaya, the scoured channel of 1876 remaining open, with raised banks. This bar was dredged out by the State of Louisiana. Similar obstructions occurred in 1878, 1879, and 1880, reforming each year at points nearer the Atchafalaya, and the channels dredged in previous years remaining open.

It may, therefore, be observed that, through all these changes, one increasing purpose runs. The process in lower Old River, during the past five years, has been that of a sediment-bearing stream discharging into an estuary. The flow from the Mississippi, now nearly constant, is building a delta with well defined channels and banks, into the wide shallow expanse of lower Old River, and towards the head of the Atchafalaya.

Other conditions confirm the probability of the continued enlargement of the Atchafalaya, and the increased outlet from the Mississippi required to supply it. Lower Red River runs nearly east, cutting through the western bank of the Mississippi alluvium. Its fall, therefore, is exceedingly slight. This slope, with sluggish current, continues down lower Old River towards the head of the Atchafalaya, where a rapid fall and great depth and velocity are encountered. A tendency must here exist to establish harmony of regimen, which can only be attained by an upward extension, and consequent reduction of the slope of the upper Atchafalaya, together with increased depth and velocity up the Old and Red rivers. But this change involves a lowering of the apex of the convex angle of the different slopes now meeting near the head of the Atchafalaya, and an increased fall from the Mississippi to that point.

We submit that these facts indicate that the Atchafalaya River is the controlling factor in the changes occurring in this locality, and that no natural limit to its enlargement can be assumed.

The increase of section at its head is as follows:

Date.	Authority.	Section.	Increase.	Per cent.	Time.
					Years.
1851	Delta survey	24,400			
1858	Abbot	28,700	4,300	16.6	7
1873	Howell	39,160	14,760	64	22
1879	Benyaurd	52,100	27,700	113.5	28

Accompanying this report are some of the surveys made at this locality. Those by Major Howell in 1873, and by Major Benyaurd in 1879, and all subsequent examinations should be of record in this office.

Another aspect of this question that will demand attention has reference to reclamation. It is probable that the Atchafalaya is quite able to carry off the discharge of the drainage basin of the Red and Black rivers. If so, the restoration of the Mississippi River levees above Red River, and the checking or closing of the outlet from the Mississippi to the Atchafalaya would reclaim the banks of the Atchafalaya, Red, Black, Ouachita, Bartholomew, Boeuf, Lafourche, Bonne Idee, Tensas, Maçon, Joe's Bayou, and other streams now annually subjected to flood from Arkansas and Upper Louisiana crevasses, and backwater from the Mississippi.

In this connection, it may be mentioned that the worst overflows on the Lower Mississippi have been caused by floods out of Red River, reinforced by crevasses in the Tensas bottom.

THIRD.—YAZOO BOTTOM FRONT.

The question of the change of slope along the Yazoo front, alluded to by Mr. Anderson in his accompanying letter, is of extreme interest and importance.

The record since 1844 here follows, and a diagram accompanies, on which are plotted the flood slopes of 1858 and 1874, and the relative condition of levees in those two years:

	Cairo.	Norfolk.	Memphis.	Helena.	Friar's Point.	White River.	Napoleon.	Ten miles below Napoleon and Niblett's Landing.	Lana.	Columbia.	Argyle and Greenville.	Sunnyside.	Grand Lake.	Vicksburg.
Distance below Cairo	0	6	248	327	342	419	429	439.44	500	502	507.9	520	542	639
1844	.....	—4.4	—1.0	—2.4	.....	.....	—1.7	.....	.....	.....	1.2	.....	.....	—0.8
1849	.....	—2.5	—3.3	—1.8	.....	.....	.....	.....	.....	.....	.....	.....	.....	—0.6
1850	.....	....	—0.6	—1.8	.....	.....	—2.4	.....	.....	.....	.....	.....	.....	+0.1
1851	.....	.....	—1.0	—4.8	.....	.....	—2.9	.....	.....	.....	.....	.....	.....	.....
1858	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1874	—2.2	—2.4	—0.3	+1.2	+2.3	.....	+2.0	+1.6	—1.3	—1.9	—2.1	—3.8	—2.5	—3.2
1859	—3.1	—3.9	—0.1	—1.0	—0.6	.....	+0.3	.....	.....	.....	.....	.....	.....	+1.3
1862	+1.2	+0.9	+0.5	+1.8	+1.7	.....	+2.1	.....	.....	.....	—1.4	—1.0	.....	+2.2
1865	—1.6	—2.1	—0.6	—0.2	0	.....	+1.8	.....	.....	.....	.....	.....	.....	—0.5
1867	+0.9	+0.7	+0.64	+1.2	+1.7	.....	+1.3	.....	.....	.....	—3.1	—3.4	—1.6	—0.1
1876	—3.18	....	—0.08	+0.4	.....	+1.2	....	+2.0	.....	.....	—1.86	—4.2	.....	—4.2
1880	—4.86	....	+0.24	—0.9	.....	+1.05	.....	+1.8	.....	.....	—2.67	—4.4	.....	—5.9

The records of 1858 and 1874 are placed in juxtaposition, to facilitate their comparison as characteristic years. That they are truly so, appears from an examination of the table. For while the diagram deals only with these two years, the table indicates that they are not arbitrarily selected, but are fairly characteristic of a change of regimen which has occurred within the past twenty-two years, and extends over two or three hundred miles of river.

It will be observed that from 1858 to 1874 the breaks and outlets from Cairo to Memphis have increased; that the relative flood heights in the lower part of this section have also increased; that a still further enlargement of outlets occurred between Memphis and Arkansas City; that throughout that distance, later and lesser floods than 1858 have risen much above the high-water mark of that year; that below Arkansas City, the swamp overflows are collected; the discharge of the White and Arkansas rivers added, and the levees comparatively maintained; and, that below this point, the abnormal elevation from Memphis down disappears.

A comparison of these two years, 1858 and 1874, also shows that the decrease of flood slope in the latter year from Memphis to Friar's Point, a distance of 94 miles, is 2.6 feet, or .332 inch per mile, and the increase from Napoleon to Sunnyside, a distance of 91 miles, is 5.8 feet, or .765 inch per mile; and that the intermediate flood plane is relatively raised from 4 to 5 feet.

These conditions have been recognized, and their cause discussed by General Abbot, n the report of the Levee Commission of 1874.

The main reasons given are as follows: 1st. The excessive discharge in 1874 from the Saint Francis basin; and 2d. The local reduction of the flood height of 1858 by crevasses along the Yazoo front.

Before the consideration of this explanation, we call attention to the remarkable flood height in 1874 along the Saint Francis front.

The discharge of that year, at Cairo, is estimated by General Abbot at 250,000 cubic feet per second less than in 1858, while its elevation, according to the only two gauges available (Cairo —2.2 feet and Memphis —0.3 foot), averaged within 1.25 feet of the great flood. This strange elevation is accounted for in General Abbot's discussions as follows:

"The Upper Mississippi being low in 1874, no water worth considering could have entered the Saint Francis bottom lands between Cape Girardeau and Cairo; and although the levees along the Saint Francis front were in worse condition in 1874 than in 1858, the crest of the wave sweeping past Cairo was so much lower that it lost far less into the swamps."

No information concerning these floods is available excepting that contained in the reports of Humphreys and Abbot, and of the Levee Commission of 1874. From an examination of these authorities, we are forced to dissent from General Abbot's argument for these reasons.

While it is certain that the escape between Cape Girardeau and Cairo was much reduced, although still important, it seems equally sure that the escape from Cairo to the mouth of the Saint Francis must have been greatly increased. According to Humphreys and Abbot, the breaks in 1858, from Commerce to the mouth of the Saint Francis, aggregated about 25 miles, the height of the levees averaging rather less than 3 feet, although some of them, across old bayous, were of enormous size. We learn from the report of the Levee Commission that in 1874 the breaks along the same locality aggregated about 143 miles, and that among them were twenty of 10 feet or greater depth, four being 20 feet deep and 100, 100, 100, and 150 feet wide, and two being 25 feet deep and 100 feet wide each. From such conditions of bank in the two floods in comparison the conclusion is inevitable that the local relief from outlets must have been experienced earlier and to a greater extent in 1874 than in 1858.

Returning now to the main argument, we submit that the discharge from the Saint Francis was not greater in 1874 than in 1858, and, granting that it was, that it could not have produced the great elevation of the flood of 1874.

The overflow height in a swamp reservoir depends upon the elevation of its source, provided the access is unimpeded. We think it may be assumed that this was practically the case in both years under consideration, and that the height of water in the swamp approximated that in the river to within the head required to overcome resistance to flow. Therefore, the Saint Francis overflow in 1874 was probably about 1.25 feet lower than in 1858, this being the half sum $\left(\frac{2.2+0.3}{2}\right)$ of differences of the only two gauges kept on that part of the river, viz, Cairo and Memphis.

This difference, it is claimed, was made up by the "extraordinary rainfall during March and April, amounting, at Memphis, to 16.77 inches, or more than double the usual quantity." If it is admissible to assume that this rainfall at one station extended over the 9,700 square miles of the Saint Francis Basin, then the collection of the surplus or unusual half into the 6,300 square miles which comprise the bottom proper, or the "lands liable to be submerged," would have given between 11 and 12 inches additional depth over that resulting from the overflow and the usual amount of rainwater in the bottom, or about .3 foot less than in 1858.

Upon these conditions is predicated a discharge in 1874 from the Saint Francis, 30,000 cubic feet per second greater than in 1858, and to this is partly attributed the 4 feet of relative and the 2 feet of absolute elevation, by which the latter year exceeded 1858.

The discharge of the Saint Francis in 1858 is thus described in the Delta report:

"It washed away miles of the insignificant levees along the Saint Francis front and poured rapidly into the bottom lands of river, which were already deeply overflowed from heavy rains and from the crevasses of the April rise. So small was the actual reservoir capacity of that region that the channels of the six large bayous, and of the Saint Francis itself, were insufficient to give water-way to the flood returning to the Mississippi. For miles above Sterling it poured over the banks themselves, washing the remains of the levees into the river. It passed like a great wave through the swamp, causing the deepest overflow ever known."

As regards the second argument, the local reduction of the flood of 1858 along the Yazoo front, by crevasses in this line of alluvial protection, we find, by examination of the same two authorities, that both floods found the left bank levees continuous and intact, and that the sum of the product of the lengths by the depths of the crevasses of the two years (1858 and 1874) aggregated respectively 146,983 and 136,482 square feet. In the latter year, Major Benyaurd states that about 10 miles of levees, not included in the foregoing aggregate, were submerged at a depth of 6 feet. On the right bank, the length of breaks aggregated more in 1874 than in 1858. We are, therefore, forced to conclude that no local relief was afforded in 1858 that was not equally effective in 1874.

No cut-off has occurred at a time or locality that could have produced the results under discussion.

We, therefore, are of the opinion that other explanation of the facts established in the diagram and table is needed, and submit the following statement and deductions. In connection therewith the historical notes of the progress of levee building should be carefully carried in mind.

The flood of 1858 is admitted to have been the greatest authenticated of recent years, generally, below Cairo. Its discharge at Cairo is estimated at 1,478,000 cubic feet per second. It found the levees to the mouth of the Saint Francis in their best condition, the breaks being less than 25 miles in length. The flood of 1874 discharged at Cairo 1,225,000 cubic feet per second, 253,000 feet, or 17 per cent. less than 1858. It

found in 300 miles breaks 143 miles long, ranging to 25 feet in depth. Yet, the crest of this flood, starting at Cairo 2.2 feet below that of 1858, steadily approached and then exceeded that mark at a point between Memphis and the mouth of the Saint Francis River. It is not possible that the waters leaving the wave, as it moved down, could have threaded the intricacies of the swamp as rapidly as the unimpeded volume of the river swept along. Nor is it possible that the waters leaving the wave at a lesser relative height could return to swell it to a greater height. The waves both years passed Helena in depleted condition, leaving part of their volume to redischarge upon the rear slope and protract the subsidence of the flood. The relative maximum discharge of the two years at Helena is estimated at 1,334,000 for 1858, and 1,160,000 cubic feet per second for 1874, a difference of 174,000 feet. At Helena, the high-water mark of 1874 read 1.2 feet above 1858.

Below Helena, further opportunity, presumably equal and unlimited, was afforded for the escape of water, yet the high-water mark of the flood of 1874, with its smaller volume, steadily exceeded that of 1858, until it culminated at Friar's Point, with an excess of 2.3 feet. This relative difference was nearly maintained (except opposite Laconia Circle) to the mouth of the Arkansas River.

The exception at Laconia Circle Levee is very remarkable. It rests upon the following evidence:

The Report of the Levee Commission of 1874 (p. 37) states that the high-water mark of 1874 at Australia and Concordia was below that of 1858.

Mr. T. S. Anderson, chief levee engineer of Mississippi, states, "Above Sunnyside, there is no system of levees on the west bank, and the water is allowed to spread over the entire western bank. This is the case except in one instance, viz, the Social Circle, a levee about 10 miles in length, and extending back from the river on the north end to high ground, protecting considerable area of country. This levee is in good condition. It is opposite Australia and Concordia. The flood line opposite this small section of levee appears lower than that above and below it. During high-water, I have very little trouble with my levees for some distance opposite the Social Circle Levee. The high-water mark at Australia was 3.5 inches higher in 1874 than in 1876. Whereas the difference was 6 inches to the contrary at Cat Fish Point, 50 miles below."

Below the Arkansas River, as at Helena, high land is found on the right bank, and the consequent reaccumulation of water from the western swamps and also augmentation of volume by the discharge of the Arkansas and White rivers. But below here, unlike Helena, the levees of the right bank are better maintained than above, particularly from Sunnyside down, while on the left bank they are kept in excellent condition. Thus, from here down, the volume is increased, and to a greater extent retained in the bed of the river, while the change in the regimen of the river, which we have been considering, disappears, and the floods again approximately conform to planes of elevation proportionate to the volume discharged.

We do not think that a change so local and yet so marked and permanent as that described, is accounted for in the Levee Commission report. A relative difference of 5 feet in the elevations of two floods at points 160 miles apart, which difference is proportionally repeated by intermediate and succeeding floods, cannot be produced by such changes of volume as are estimated and recorded, unless other operations are brought into action. We are, therefore, of the opinion that the bed is raised and the effective section impaired throughout that part of the river under discussion, as the results of outlets and the local abandonment of levees.

We beg leave to submit the following conclusions:

1. That bayous and overflows afford no permanent or uniform relief, but produce changes of regimen detrimental to navigation, and cause destructive floods.

2. That the direct influence of a levee system is to improve navigation and prevent destructive floods by the establishment of a regimen, and the elimination of varying and abnormal local conditions.

3. That the conservation of flood waters by artificial embankments is becoming of greater importance every year, both in preserving navigation and in preventing destructive floods, from the recession of the banks to lower levels, and has already, in many parts of the river, become essential.

4. That the act under which we serve contemplates the preparation by this commission of a complete plan for the regulation of the river and its banks. Any such plan must include the control and uniform maintenance of such conditions of the river banks as are consistent with the principles controlling the works already recommended by us. The present provision for such maintenance, by the States and riparian owners, is inadequate and hazardous.

Respectfully submitted.

B. M. HARROD.
CHAS. R. SUTER.

Gen. Q. A. GILLMORE,
President Mississippi River Commission.

LETTERS OF MR. T. S. ANDERSON.

1.

COLORADO SPRINGS, COLO., *August* 11, 1880.

DEAR SIR: Upon my arrival here I received your communication of the 23d of July, forwarded from Greenville, Miss. I trust what I may say in regard to our levees may reach you in time to assist you in your statement to the Mississippi River Commission.

The line of levees maintained under the auspices of the Board of Mississippi Levee Commissioners extends from a point in Coahoma County, 4 miles above Sunflower Landing, down to within 1 mile of the line between Issaquena and Warren counties, and is about 220 miles in length. It protects the country from a river front of about 285 miles.

The average location of the levee back from the river bank may be put at 300 to 400 yards, except where it cuts across bends, where, of course, it is farther. The average height of the levees is from 7 to 8 feet, the minimum being 4 feet, and the maximum 30 to 40 feet. The grades of our levees are not uniform, being in some places only a few inches, and in others as much 6 and 8 feet above the flood lines of recent years. Any reference of grade that may have been made in the past to the high-water in 1858, is of no avail now. In fact there are no records in my office to show that the flood of that year was ever used as a criterion. From the best evidence I have been able to obtain as to the water mark of 1858, the water in the upper half of our district in 1874 and 1876 was higher by at least 1 foot, while in the lower half of the district it was from 3 to 6 feet lower in 1874 than in 1858. As an evidence of this change in the flood line, all the new levees in the upper portion of the district have been made higher than the older ones, and the grades of the old levees have been raised in order to keep the high-waters of recent years from going over them. In the lower portion of the district the reverse is the case, and levees which were not of sufficient height a score of years ago, now stand from 4 to 6 feet above the highest waters we have.

The grades of all levees built since 1874 are referred to the high-water of that year, it being the highest known for many years. As a rule the levees are built 3 feet above the water of 1874, and have a cross section of 8 feet crown and slopes of 3 to 1 on either side.

Owing to the absence of high-water for several years past, we have been enabled to close all the crevasses, so that our line now is continuous and unbroken.

A large portion of our old levees are of insufficient height and strength and stand urgently in need of repairs and enlargement.

The most dangerous portion of our levee system is that which extends from Terrene to Greenville, a distance of about 80 miles. Being opposite and below the mouths of the White and Arkansas rivers, these levees are subjected to a greater pressure of water, in consequence of which they are much larger than the average levee of the district. But withal, they are more subject to crevasses in time of high-water.

The Hushpucana Levee in the upper end of the district, the Bolivar Levee in Bolivar County, and the Cammack Levee in Issaquena County are large and very important levees to the large extent of country depending upon them. The Hushpucana Levee is 500 feet in length, is 40 feet high at the deepest part of the bayou, and averages about 25 in height. The Bolivar Levee, where it crosses the head of Lake Bolivar, is 27 feet in the highest place and averages 18 feet in height for a distance of 600 or 800 feet. The Cammack is not so large or important as the above-named levees, yet it is one of considerable importance, and always gives more or less trouble in time of high-water.

Our levee district is composed of the counties of Bolivar, Washington, Issaquena, and Sharkey. Funds for construction and repair of levee are raised by a tax on cotton (usually one dollar per bale) and an ad valorem tax on realty and personalty of five mills on the State tax. From these sources a fund of from $100,000 to $150,000 per annum is realized, which is wholly insufficient to do the extensive repairs needed, in addition to building the new levee required each year.

For the protection of a considerable extent of the upper part of the district the levees have been extended about 15 miles into Coahoma County, and though these levees are among the most expensive and protect much of the lower part of that county we derive no tax, or contribution whatever from it. Immediately above our levees is a gap of some 8 or 10 miles, where there is no levee and where a great body of water flows through every year, overflowing a great deal of rich land and finally passing off into the Sunflower River.

There are other gaps in the levees of Tunica and Coahoma counties, but I cannot give you any account of them, neither can I furnish you any information in regard to the Yazoo Pass Levee.

I will refer you to Capt. W. O. Flinn, civil engineer, Helena, Ark., for any information you may desire concerning the levees of the "upper district."

My estimate of what will be required to make the levees of our district a perfect and effective system, is about 6,000,000 cubic yards of earth work. Fully four-fifths of this amount is needed in enlarging the levees in the upper half of the district. The remainder is needed for repairs in the lower part of the district and for constructing new levees where the old ones are about to cave off.

Hoping you may be able to cull from the foregoing the information you want, and that you have suffered no inconvenience by the delay, I remain, very truly yours,

T. S. ANDERSON,
Chief Engineer Board Mississippi Levee Commission.

Maj. B. M. HARROD, *New Orleans, La.*

2.

MANITOU SPRINGS, COLO., *September* 19, 1880.

DEAR SIR: Your letter of the 23d August, after having followed me from place to place, has finally reached me. I will have the tracings you desire made as soon as I return to my office, which will be early in the coming month. I regret that I have not the time at this writing to give you at length my views and opinions regarding the changes which have been and are still being worked in the flood time along our front. The study is one almost as perplexing as that of our southern scourge.

I am of the opinion that the changes which I described in my last letter are in a measure due to the effects of levees, *i. e.*, the levees being intact (with the exception of one or two places), from Sunnyside, Ark., down to the lower end of my district, and continued on the Mississippi side, the water is always confined to the bed of the river, and consequently dredging or scouring out its channel and making its bed and flood line deeper and its way easier to the southward. On the other hand, above Sunnyside, Ark., there is no system of levees on the west bank, and the waters of the river are allowed to spread broadcast over the entire western bank in time of high-water. This is the case except in one instance, namely, the "Social Circle," a levee about 10 miles in length, and extending back from the river on the north end to high ground, protecting a considerable area of country. This levee is in good condition. It is opposite Australia and Concordia, Miss., and very singular to say, the flood line opposite this small section of levee appears lower than that above and below it. I have not made instrumental investigation of this place, however, and what I say could only be substantiated or refuted by such an investigation. I have only noticed the effect upon the levees on my side of the river. During high-water I have very little trouble with my levees for some distance opposite the "Social Circle Levee." And the high-water mark at Australia was 3½ inches higher in 1874 than 1876. Whereas the difference was 6 inches to the contrary at Cat Fish Point, 50 miles below. This is the portion of the river which I described as giving the most trouble on account of the increasing elevation of the flood line, that is, from the upper end of our levee district down to Greenville. While I am of the opinion that the levees have their effect upon the regimen of the river, I am under the impression that the changes in the flood line in question are attributable more to the conformation of the river than to any other one cause. The river of the upper end of our district is exceedingly crooked, while on the lower portion it is comparatively straight.

Please excuse my hurriedly written and disconnected letter. I should be very glad to have you visit me at Greenville during the fall.

Very truly yours,

T. S. ANDERSON.

LETTER FROM MR. W. O. FLYNN.

MEMPHIS, TENN., *September* 4, 1880.

DEAR SIR: Yours of the 25th August was forwarded to me here; also the report of the Mississippi Commission, for which accept my thanks. I have been trying to get one for some time.

I will try to answer your questions as near as I can. The answers will nearly all be given from memory, and consequently will not be perfectly accurate.

EXTENT.

I suppose by that you mean the length. The levee begins at the foot of the hills in Desoto County, on the lower side of Horn Lake. By reference to Hardee's map of

the State of Mississippi you will be able to locate it; thence, in a southwest direction, 7 miles to the Mississippi River at Norfolk Landing, 25 miles below Memphis. Horn Lake (south side) is the northern boundary of the levee district.

From Norfolk Landing down to Commerce Landing the levee is close to the river. From Commerce it leaves the river across the point, and comes to the river again at Moohn's Landing. From Moohn's it leaves the river and crosses the point, and comes to the river again just above Austin. From Austin to O. K. Landing, 2 miles, it is on the river bank. From O. K. Landing it goes in back of Flower Lake and comes out on the river again at Trotter's Landing, 2 miles above the south line of Tunica County. From Trotter's Landing it goes in back of Eagle Lake, and continues (back 2 miles) from the river until it gets to Thompson's Landing, 2 miles above Yazoo Pass and 6 miles below the Coahoma County line. From Thompson's Landing to Delta it is on the river bank—that is, say, 300 yards back. From Delta it leaves the river again and comes back to it again just above Friar's Point. From Friar's Point down to Miller's Landing it is on the river; and from Miller's it goes in back of Old River and comes out on the main river just above Island 63, or McCloud's Landing. From McCloud's Landing to the lower end of the district, the levee is very badly broken and too low in many places, and that immediate country is overflowed every year. The original levee (before the war) ran around the point to Sunflower Landing. Back in from McCloud's Landing is where the gap is between the two districts.

The trouble has been the excessive cost of putting a levee around the point and what is called the Lewis Swamp or Square Lake country.

Going in the other way, the trouble is to get rid of the water flowing through Hushpuckana Bayou. There has been a good deal of local agitation and loud complaint from this neighborhood on account of being taxed for levees and getting none. Recently an act was passed in the legislature exempting them from taxation.

The distances for the above are about as follows, and I would suggest that you compare them with Hardee's map for correction:

	Miles.
From the foot of the hills to Norfolk Landing	7
From Norfolk to Commerce	15
From Commerce to Austin	18
From Austin to Trotter's	12
From Trotter's to Thompson's	9
From Thompson's to Yazoo Pass	2
From Yazoo Pass to Delta	4
From Delta to Friar's Point	4
From Friar's Point to Miller's	2
From Miller's to McCloud's	18
From McCloud's to Sunflower Landing, in back across the point to lower district levee, about	10
	101

CONDITION.

For the last five or six years District No. 1 has had no organization, and did nothing except a few repairs.

Last year, while I was chief engineer of the Mobile and Northwestern Railroad, I attended to repairing and strengthening the Yazoo Pass levee, the Gordon Break levee, and the Delta Break levee.

So far as I can learn, the principal trouble with the levees in this district is their being too low, having been worn off by being used as wagon roads. During the last high water there were no breaks in the levee in this district.

The only places I have heard of being in danger of caving in are Desoto Front, a few miles below Norfolk Landing; levee between Austin and O. K. Landing—this is across the head of Beaver Dam Lake; and levee at Trotter's Landing. There may be others, but I have not heard of them, or do not recollect them.

DIMENSIONS.

These levees were pretty much all built before the war, under the original levee board. The standard then was: slope on river side, 4 to 1; on the land side, 3 to 1; crown, 10 feet.

When District No. 1 was organized, in 1871 I think it was, the chief engineer adopted the same dimensions, and they were adhered to as long as the funds held out. When funds began to get scarce the dimensions were cut down to 3 and 2 to 1 and 8-foot crown, and 3 and 2 to 1 and 6-foot crown. There was very little of the small-sized levees built.

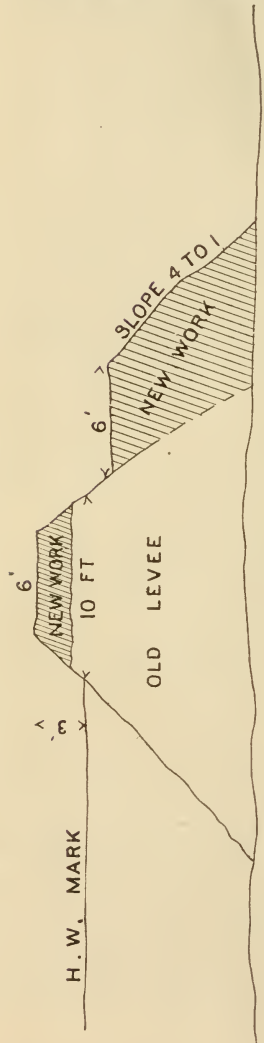
The largest levee in the district is the levee between Austin and O. K. Landing, and that, I think, will average 13 or 14 feet high. There are several levees that are

higher, but they are across sloughs or bayous. The average height, I should suppose, would be about 9 feet for the district, allowing the levee to be 3 feet above high-water mark.

SPECIAL LEVEES.

The special levees, or those known as such, are as follows, viz:

The McKinney Bayou Levee, 2½ miles above Austin, in Tunica County.



McKinney Bayou is a constant flowing stream and empties into the Mississippi River, and for that reason has to have a culvert in it. The culvert is the trouble. Depth of bayou at levee crossing, about 35 feet. Width of bayou, 250 feet.

The Yazoo Pass Levee, 7 miles above Friar's Point, in Coahoma County.

When this levee was rebuilt, it was 50 feet high, slopes 4 to 1 on each side, and 20 feet crown. This winter it was raised and repaired, having been worked very much by being used as a road and a steamboat landing.

The crown was sloped up to 10 feet. There was 8,000 cubic yards of material put on it.

Length of Yazoo Pass levee (proper), 300 feet.

Gordon Break Levee, three-fourths of a mile below Yazoo Pass levee. Length, 500 feet; height, 27 feet; crown, 6 feet. This past winter I had 5,000 cubic yards put on the back of it and made the land side slope 4 to 1. The front slope was intended to be 4 to 1, but lacked from 6 to 10 feet of being raised high enough to make it a plane from edge of crown to foot of slope. When I had charge of fixing it the water was so high on it that I did not like to do anything with it.

Delta Break Levee.—This is about 1 mile above Delta, Coahoma County.

This levee has broken three times. Length of break, 500 feet; height of levee, 17 feet; crown (now), 6 feet; back slope, 3 to 1.

This past winter put about 5,000 cubic yards on this levee.

Both this and the Gordon Break levee were given a cross section as follows:

The Miller Break, 1 mile below Frair's Point. This levee has broken three times. Last time it was rebuilt it was given a slope of 4 to 1 on each side and 8 feet crown.

Port Royal Levee, 3 miles below Friar's Point, has broken two or three times. I forget the dimensions.

Rand Break.—This I forgot to mention in its regular order. It is about 1½ miles above Trotter's Landing. It has broken three times. Last time I rebuilt it in 1875, and it has stood since.

I canont make any tracings for you, as I have neither maps nor profiles of the Pass levee or any of the others. Everything was left with the levee board, and I think are pretty much all lost. At present I have not time to make any surveys for you, as I am engaged in a contract removing the bluffs here for the extension of the Mississippi and Tennessee Railroad to the Union Depot. For any changes in flood lines I would refer you to J. B. Miles, signal officer at Helena, Ark.

In one of my note books I have the high-water of 1844, 1858, and 1862, I think it is, and while at Friar's Point one day I moved them and put them on the jail in that town. As soon as I can find them I will send them to you. I consider them reliable, as they were pointed out to me by J. G. Miller, who had nails driven in a tree on the river bank. Thinking they might be of service some day, I took my level and moved them. If I have not been sufficiently explicit in my descriptions or explanations, if you notify me of it, I will take pleasure in making them intelligible to you.

I do not think it would be very difficult to explain the cause of the breaking of the above levees, for I think they all have local defects.

I have been on the Mississippi River several years, and in a high-water time con-

Comparative Diagram of Floods of 1858 and 1874
and
Condition of Levees in those years

Squares horizontally 30 miles
" vertically 15 feet

Cairo · Norfolk · Columbus · Memphis · Helena · Napoleon · 10 m below Nibletts · Arkansas City · Gaines Ldg · Luna Columbia · Argyle Greenville · Sunnyside · Grand Lake · Keys Ldg · Vicksburg

0 · 75 m · 150 m · 225 m · 300 m · 375 m · 450 m · 525 m · 600 m

Cairo · New Madrid · Hills adjacent · Fort Pillow · Memphis · Helena · Scrubgrass Creek · Mouths of White and Arkansas Rivers · Gaines Ldg · Hills adjacent · Skipwiths Ldg · Vicksburg

1858 · H W 1874

Horizontal lines are levees and breaks
Inclined " " flood slopes of 1858 and 1874

	Right bank above Helena	below "	Left " Memphis
Aggregate breaks	26.3	57	0
" "		62.4	9.6
" "			5.6
" "	143.4	62.5	8.2

Before flood of 1858
After " " "
Before " 1874
After " "

Levees submerged 10 miles

House. Ex. Doc. No 95. 3d Sess. 46th Cong.